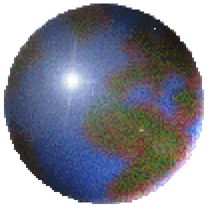


Wisconsin County Coordinate Systems: WLIA Task Force Report on the Issues

WSLS Annual Institute

January 27, 2005

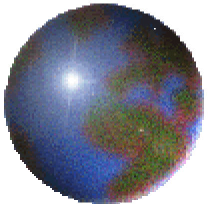
Ted Koch - State Cartographer

Diann Danielsen – LIO Manager, Dane County

Jerry Mahun – Civil & Environmental Engineering Technology, MATC

Al Vonderohe – Dept. of Civil & Environmental Engineering, UW-Madison

Today's Presentation



Diann - ***WCCS: Why & What + Concerns***

Jerry - ***Wisconsin Coordinate Systems: The Technical Foundation***

Al - ***WCCS: Emerging Issues and Solutions***

Ted - ***Summary: Where are we headed?***

WI Coordinate Systems Task Force

- Mission:
  - Analyze and document the foundations of the WCCS
  - Investigate, analyze and document software implementations of WCCS
  - Investigate the redesign of the WCCS
  - Register WCCS with standards setting organization
  - Document WCCS proceedings
  - Develop user-focused documentation
  - Evaluate and make recommendations regarding statutory changes
  - Present TF recommendations to WLIA Board

Task Force Members

- Brett Budrow St Croix County
- Tom Bushy ESRI
- Diann Danielsen Dane County
- John Ellingson Jackson County
- Bob Gurda State Cartographer's Office (ended 4/30/04)
- Pat Ford Brown County
- Gene Hafermann WI Dept of Transportation
- David Hart UW-Madison Sea Grant
- Ted Koch State Cartographer, Chair
- Mike Koutnik ESRI
- John Laedlein WI Dept of Natural Resources
- Tim Lehmann Buffalo County
- Gerald Mahun Madison Area Technical College
- David Moyer, Acting State Advisor Nat'l Geodetic Survey
- Kent Pena USDA-Natural Resources Conservation Service
- Karl Sandsness yres Associates
- Glen Schaefer WI Dept of Transportation
- Jerry Sullivan WI Dept of Administration
- Peter Thum GeoAnalytics. Inc.
- Al Vonderohe UW-Madison, Dep't of Civil & Environmental Engineering
- Jay Yearwood City of Appleton
- AJ Wortley State Cartographer's Office

Task Force Accomplishments

- 9 meetings in the past 12 months
- Documents:
  - Equations & Parameters for WI Coordinate Systems, (Jerry Mahun)
  - WCCS Test Point Data
  - Products matrix
  - Proposal to redesign the WCCS
- WTM parameters registered with ESPG
- Presenting TF work and conclusions to the professional community

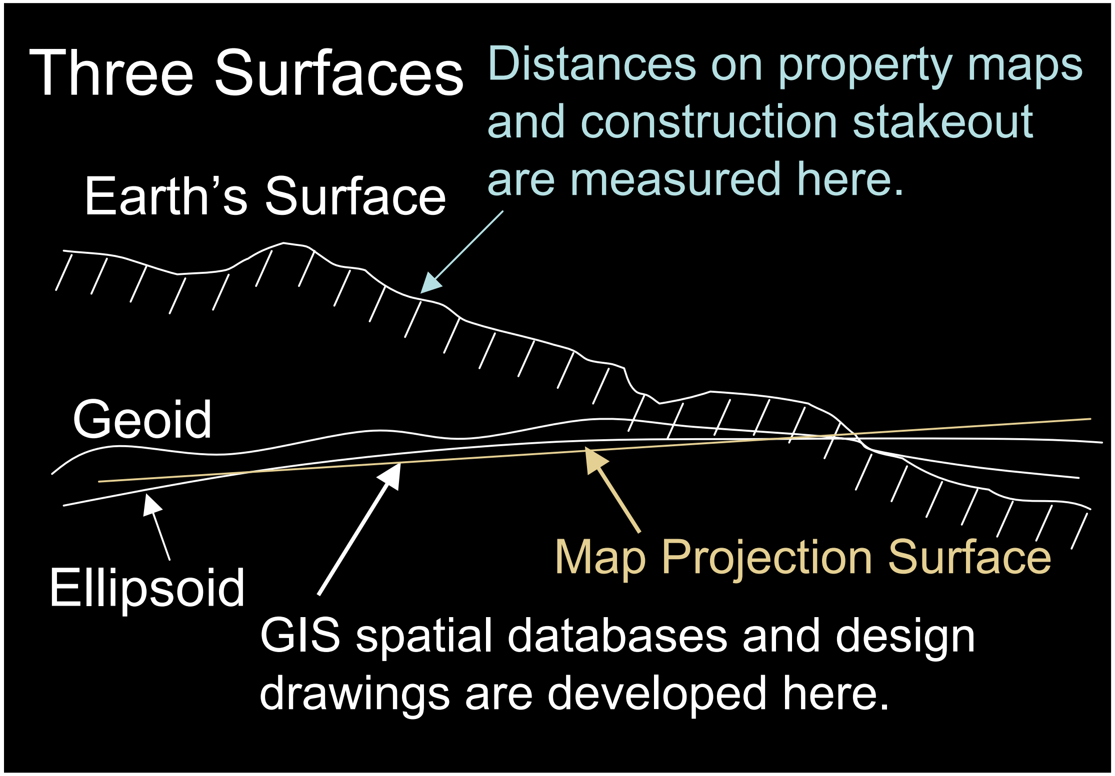
Next:

- **Local coordinate systems and the WCCS: Why and What + Concerns**
  - Diann Danielsen

Why a Local Coordinate System?

Regional coordinate systems require ground-to-grid conversions to relate field surveyed coordinates to projected mapping coordinates

- Easy for staff to misapply or forget conversions
- Huge conversion effort for historic records
  - Property maps have tens of thousands of ground-level distances on them. Too difficult to convert to map projections for GIS.
  - Design drawings have tens of thousands of map projection distances on them. Too difficult to convert to ground distances for construction stakeout.



Wisconsin Local Coordinate Systems

- Old WisDOT county coordinate system used an *average* elevation and scale factor for each county to ease conversion between grid and ground values
  - Typical project-based approach; does not preserve a precise mathematical relationship with other coordinate systems.
- Several Wisconsin counties began defining and adopting coordinate systems for local use
- WisDOT desired a unified set of county coordinate systems for the agency's large-scale mapping and roadway design activities that would be:
  - Standardized and mathematically relatable to other systems
  - Incorporate existing local county coordinate systems

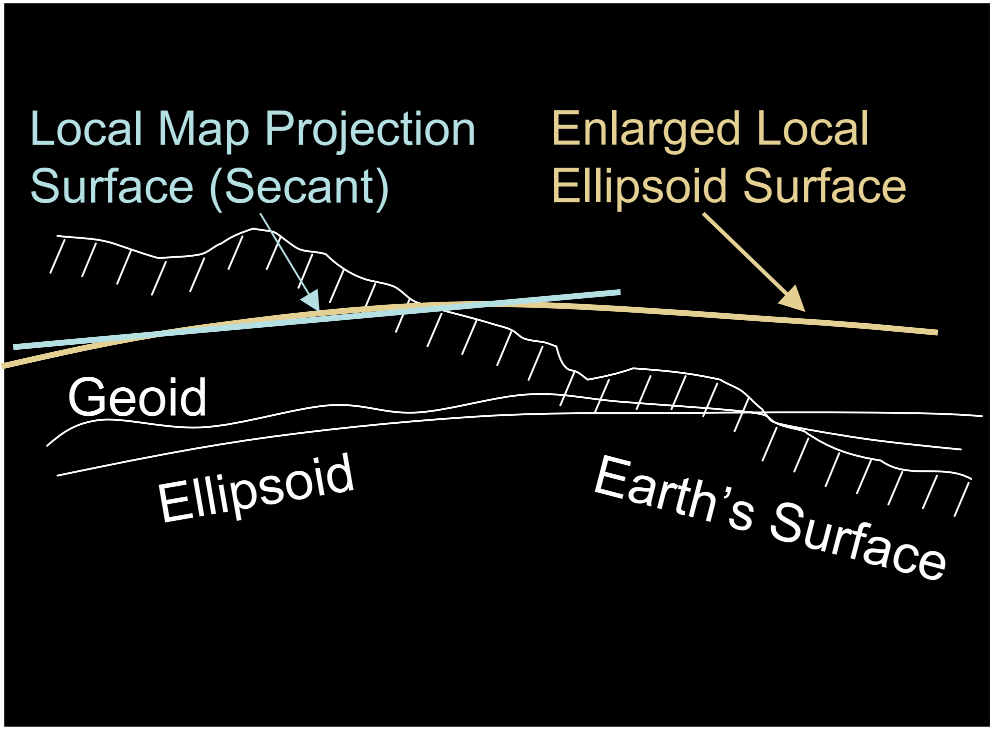
Solution….

- Develop map projections that are even more localized than state plane coordinate projections
  - No significant differences between ground distances and map projection distances
  - Ground distances can be used directly in spatial databases and grid (design) distances can be used directly for stakeout.

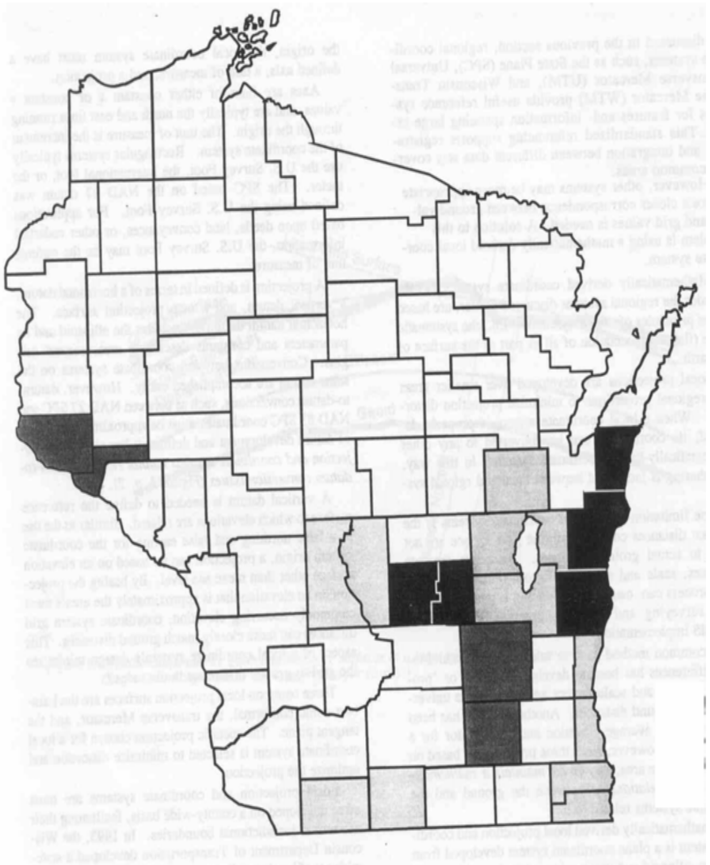
Wisconsin County Coordinate System

- Fairview Industries was hired by WisDOT in 1993 to develop a consistent statewide set of county based coordinate systems

- This design raised the ellipsoid surface to near ground level to minimize ground and grid differences



Wisconsin County Coordinate System



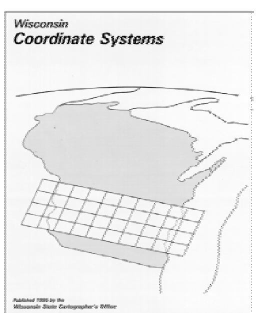
- 59 separate map projections (Lambert and Transverse Mercator)
- 72 counties – some share a projection

Use and Adoption of the WCCS

- Not officially adopted in statute (no current statutory home for coordinate system definition outside of a platting context)
- Chapter 236 updates were crafted to recognize and allow the use of WCCS for platting purposes
- WLIP & Task Force surveys indicate the WCCS has been adopted for use in ¾'s of Wisconsin counties

Use and Adoption of the WCCS

- WCCS has become a key component of the WLIP, recognized as a voluntary or de facto standard, and supported by a number of educational resources
  - Statewide educational rollout in mid-1990’s
  - Hardcopy and online resources



http://www.geography.wisc.edu/sco/pubs/wiscoord/wiscoord.php

Emerging Issues

- Multiple county coordinate systems
  - Jackson County Official Coordinate System (county adopted)
  - Jackson County Coordinate System (WisDOT developed)
- Different naming conventions
  - Badger County Coordinate System; Badger County Geodetic Grid; Badger County Coordinate Grid; WCCS – Badger County; WCCS for Badger County; WCCS – Badger Zone
- Questionable use of datums
  - WCCS designed specifically for use with NAD83(1991)
  - WisDOT plats being filed using WCCS – Badger Zone; NAD83(1997)
- Variations create confusion when communicating and trying to convert data

Other Concerns

- Vendor Implementation
  - Difficult because of the WCCS's unconventional design; mathematically correct, but less understood
  - Vendor implementation methodology differs, resulting in different coordinate values for the same feature
- Lack of Formal Registration
  - Some local systems adopted in ordinance; most are not
  - Not registered with European Petroleum Survey Group/EPSG
    - Aids consistent interpretation and implementation
- Lack of State Custodian/Oversight
  - No designated entity responsible for Wisconsin coordinate systems or other spatial reference parameters (land and water datums, geoid models, ellipsoids, etc)

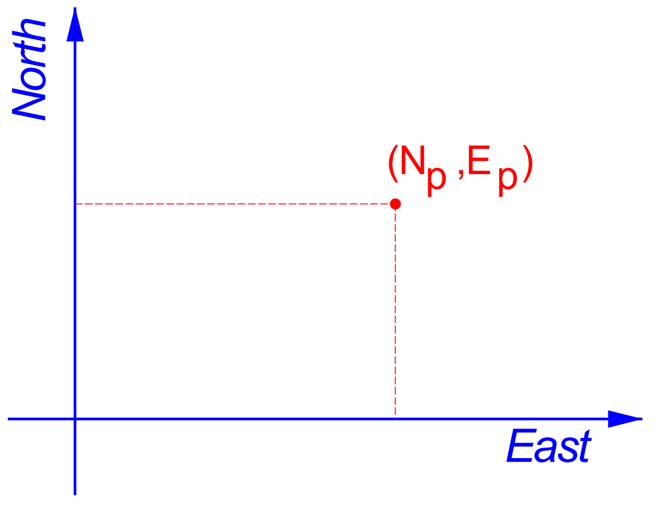
Defining Concepts
Coordinate System Development
Two-Dimensional Rectangular Coordinate Systems
Formal Coordinate Systems in Wisconsin

Jerry Mahun
Madison Area Technical College

Defining Concepts

To develop a coordinate system:

- Relate non mathematical three dimensional earth to a mathematical 3D model.
- Project 3D model into a 2D plane
- Define coordinate axes and units



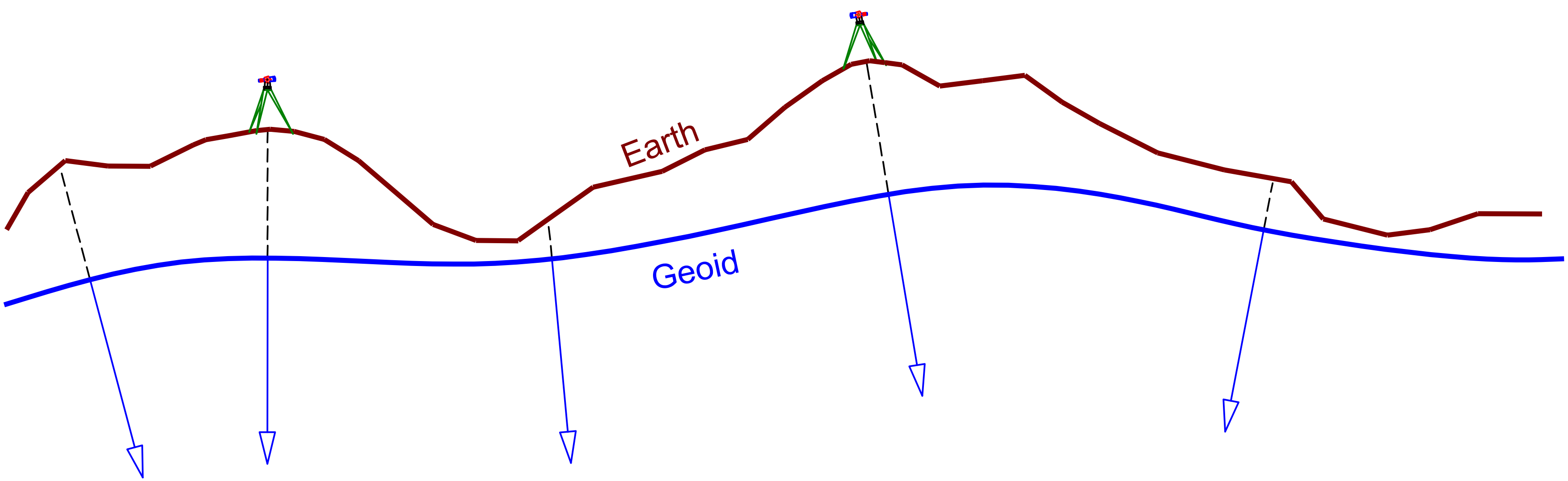
Earth Models

Earth Physical Earth; Terrain

Entity on which measurements are made.

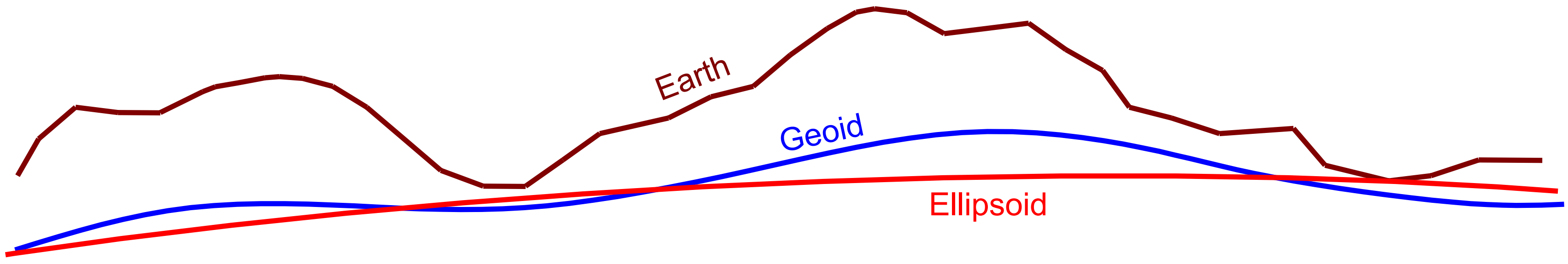
Geoid An *equipotential* surface

A surface on which gravity
and centrifugal forces are balanced.



Directions of gravity

Earth Models

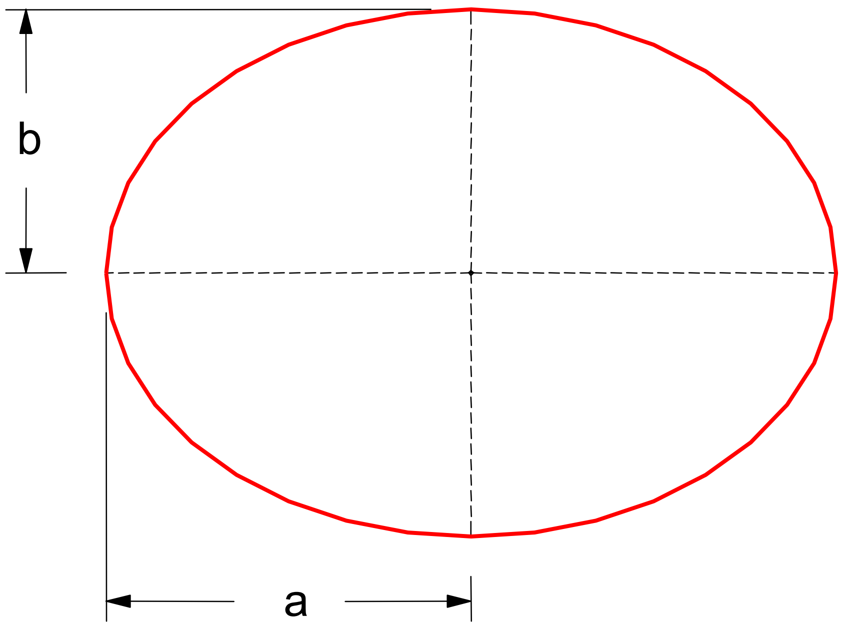


Ellipsoid

The ellipsoid is a mathematical surface used to approximate the geoid.

Defining Concepts

Ellipse Parameters

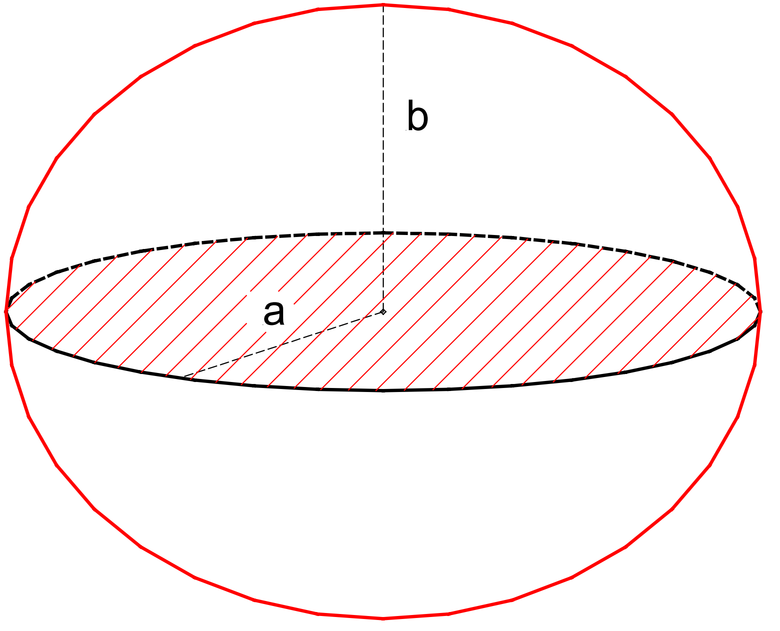


a = semimajor axis
b = semiminor axis
f = flattening
e = eccentricity

$$f = \frac{a-b}{b}$$

$$e = \frac{\sqrt{a^2-b^2}}{a}$$

Ellipsoid



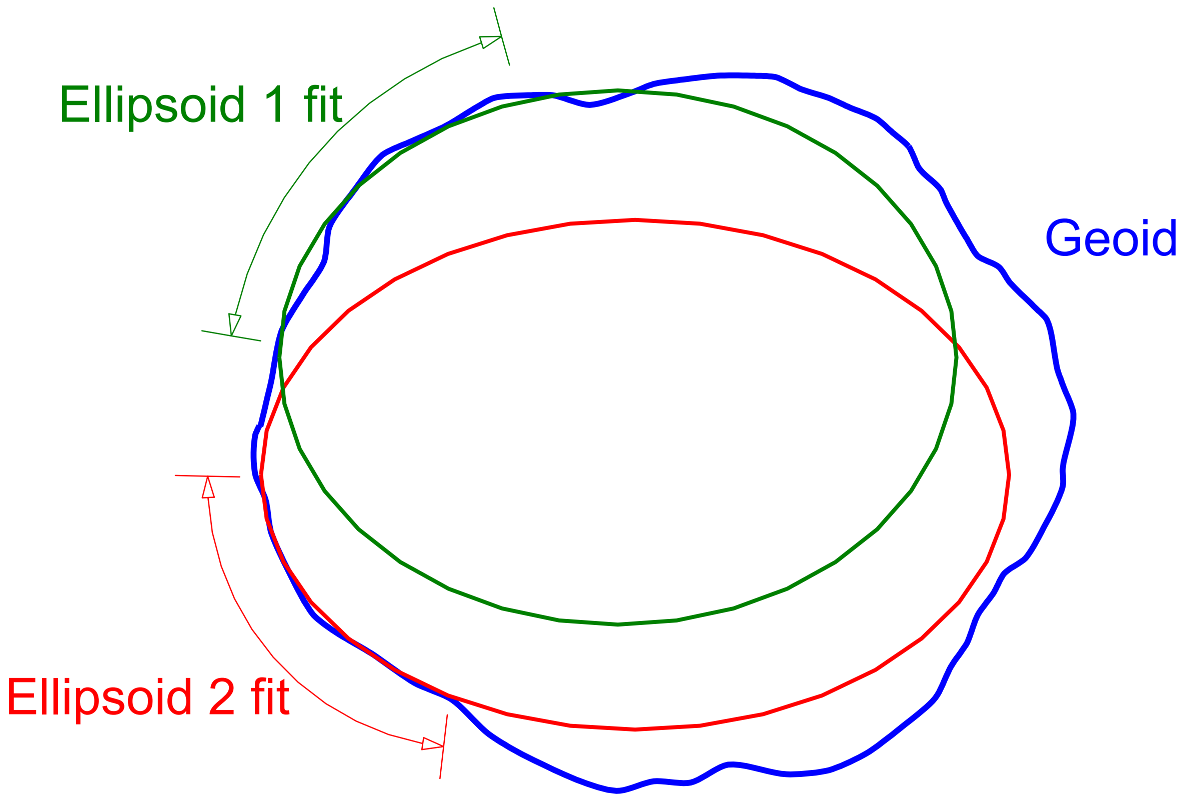
Typical Ellipsoids

Ellipsoid	*a (meters)*	*b (meters)*	*1/f*
Clarke 1866	6,378,206.4*	6,356,583.8*	1/294.9786982
GRS 80	6,378,137.0*	6,356,752.31414	1/298.257222101*
WGS 84	6,378,137.0*	6,356,752.31424	1/298.257223563*

**defining parameters*

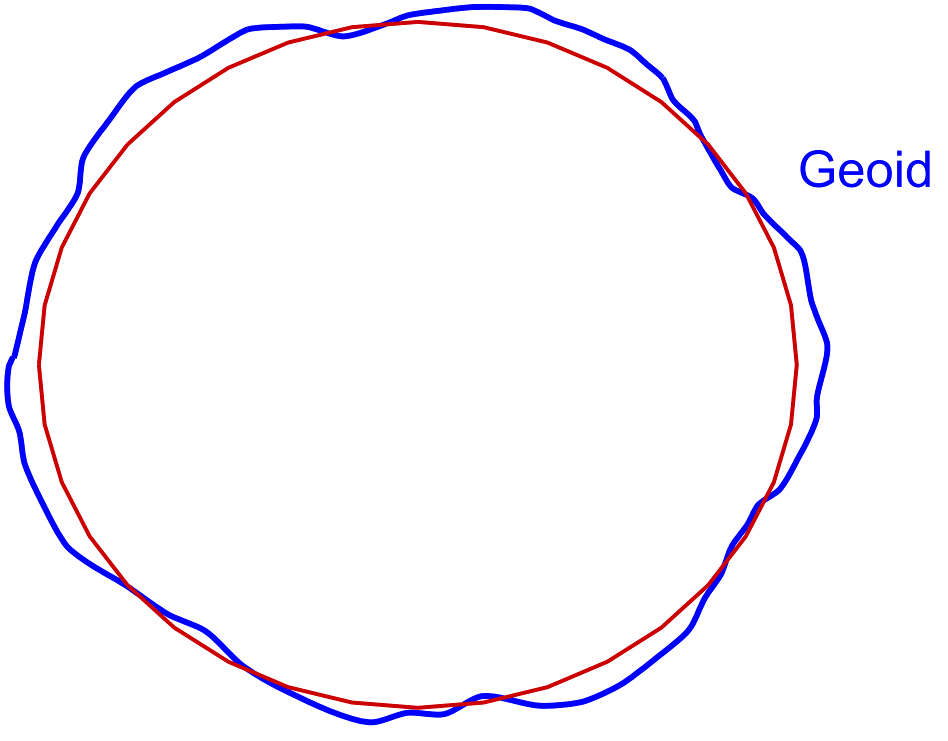
Fitting an Ellipsoid

Regional Fitting

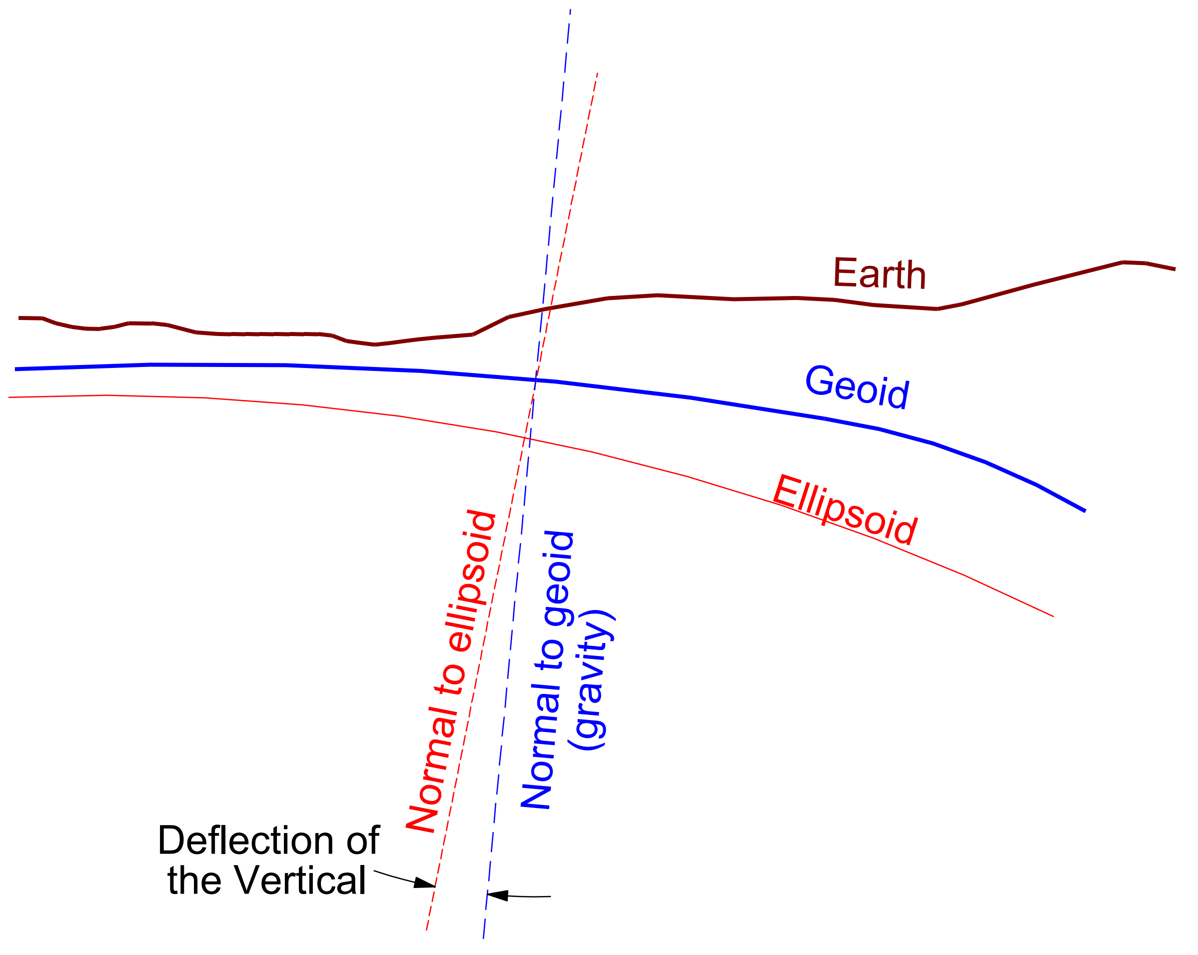


Fitting an Ellipsoid

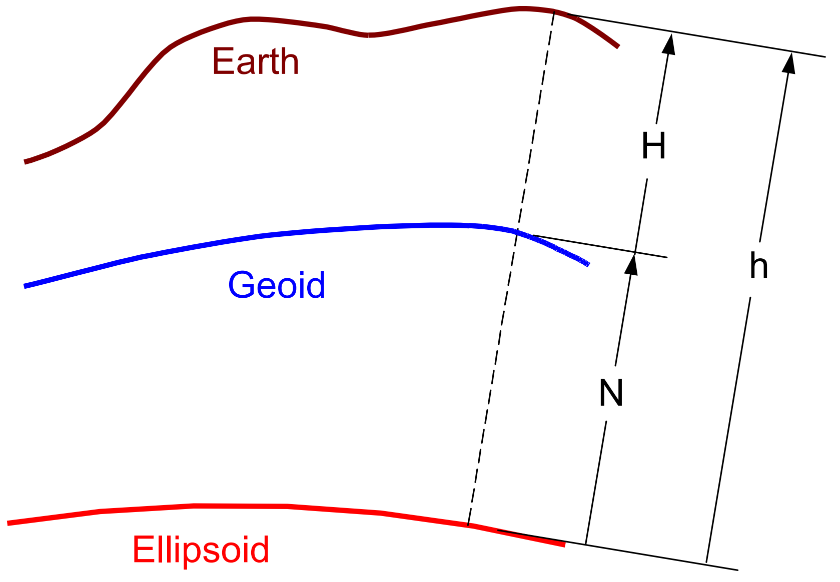
Global Fitting



Fitting an Ellipsoid



Fitting an Ellipsoid



H: orthometric height

N: geoid height
(+) if geoid is above ellipsoid
(-) if geoid is below ellipsoid

h: ellipsoidal (geodetic) height

$h = H + N$

Datum

datum

Any quantity or set of such quantities that may serve as a reference or basis for calculations of other quantities.

datum, geodetic

A set of constants specifying the coordinate system used for geodetic control, i.e., for calculating coordinates of points on the Earth.

A datum consists of the ellipsoid and its geoid fit.

Defining Concepts

Datum

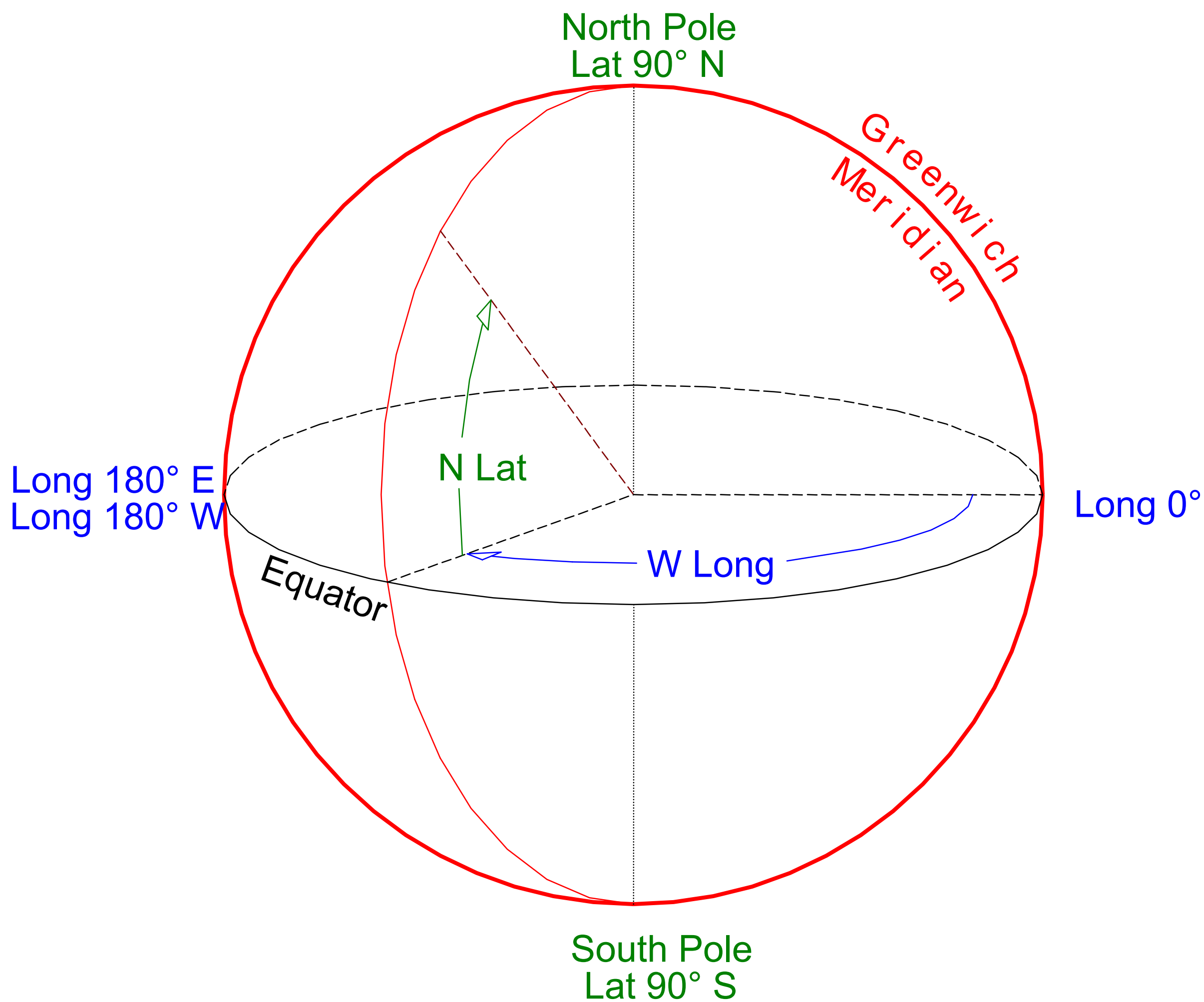
Datum	**NAD 27**	**NAD 83**
Ellipsoid	Clarke 1866	GRS 80
Fit to	North America	World
Criteria	Origin at Meades Ranch, KS; no geoid separation. *Azimuth to Waldo fixed.*	Ellipsoid centroid coincides with earth's mass center. Semiminor axis set parallel with polar axis
Approx Number of Control Stations	25,000	272,000

NAD 83 has been adjusted three times in Wis:

NAD 83 (1986) - Original national adjustment
NAD 83 (1991) - WI HARN incorporated
NAD 83 (1997) - Re-observed GPS stations

Three-Dimensional Reference System

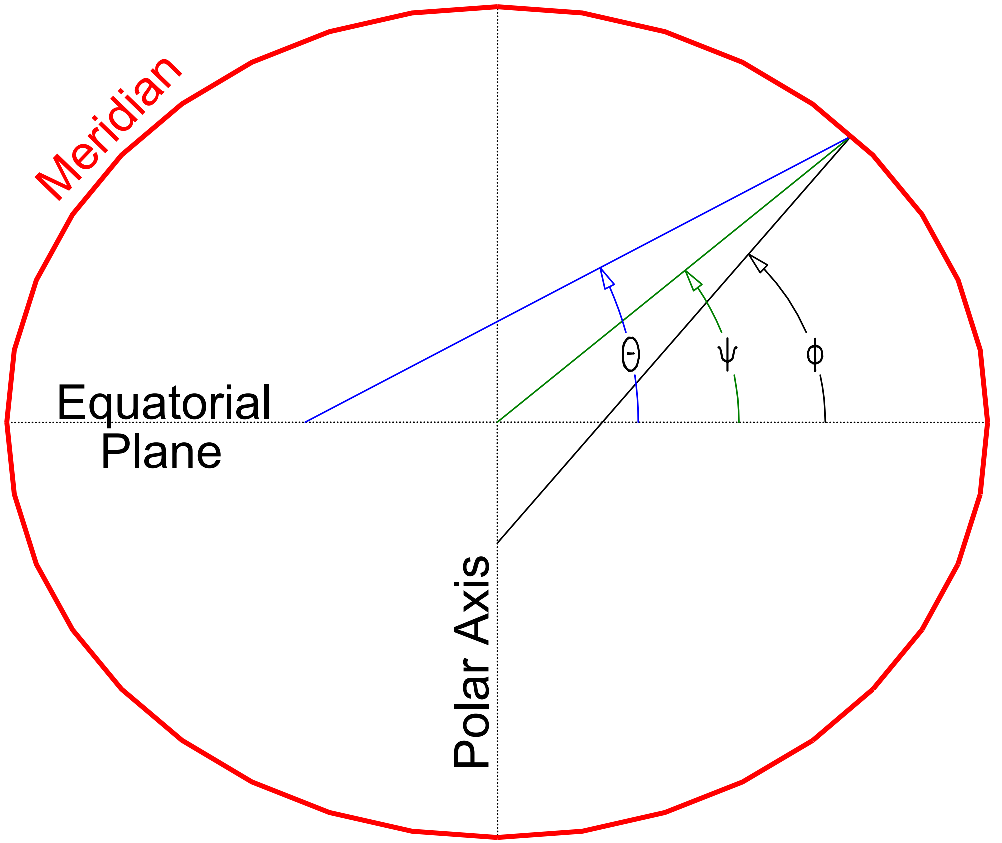
Spherical Coordinates



Coordinate System Development

Three-Dimensional Reference System

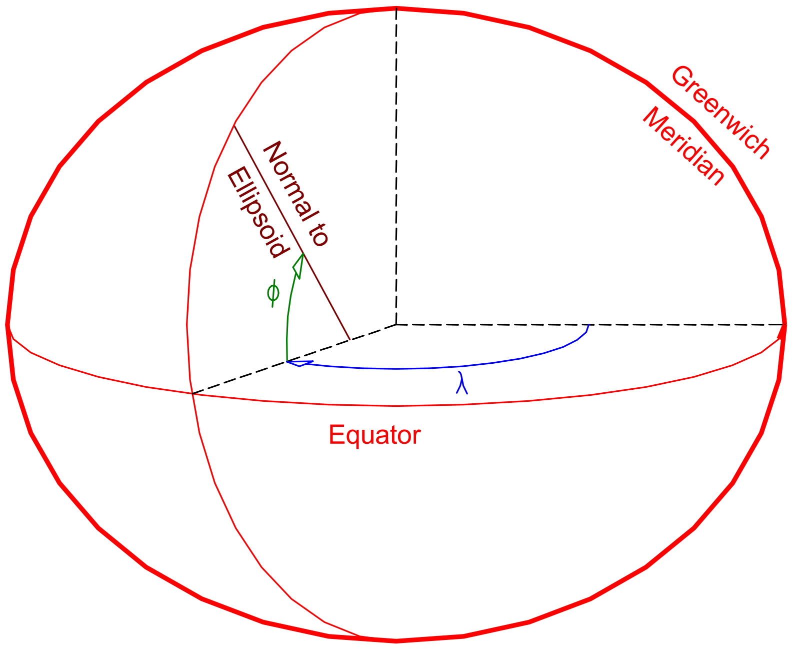
Spherical Coordinates



Types of Latitude
- Θ : Astronomic latitude
- ψ : Geocentric latitude
- φ : Geodetic latitude

Three-Dimensional Reference System

Geodetic Coordinates

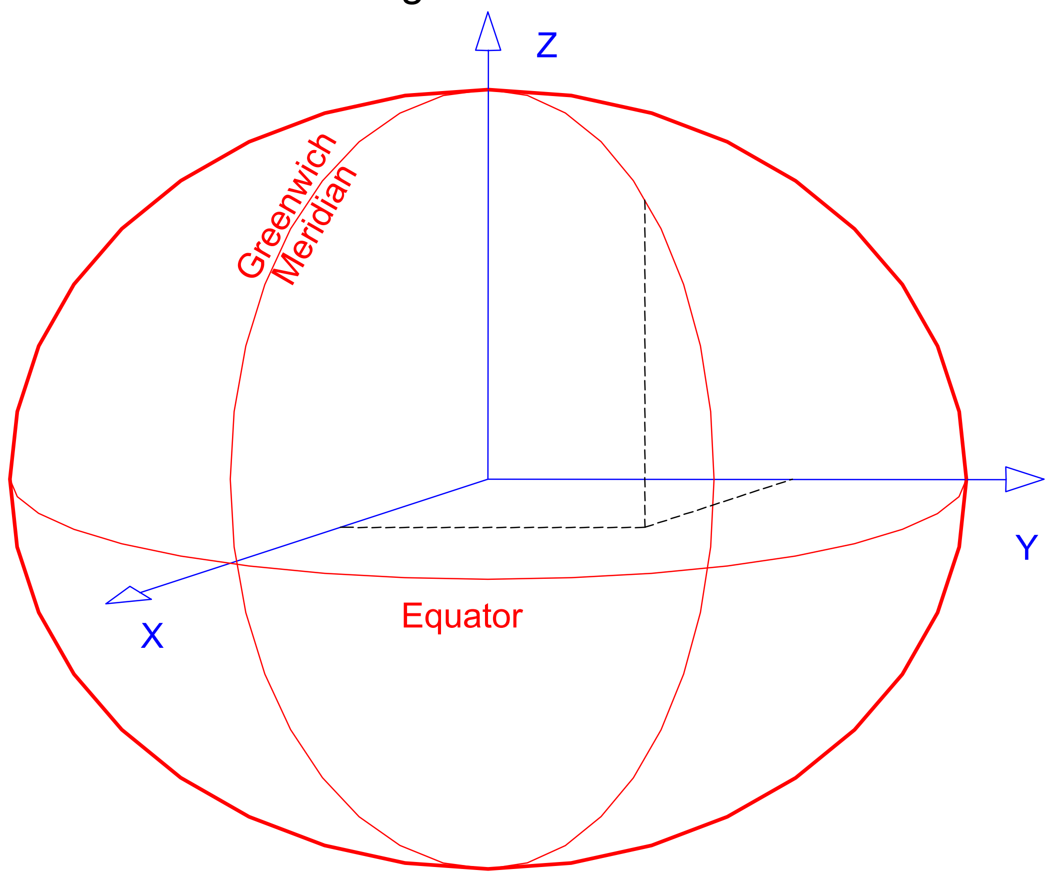


Three dimensional position of a point is expressed by:

- ϕ geodetic latitude
- λ geodetic longitude

Three-Dimensional Reference System

Rectangular Coordinates

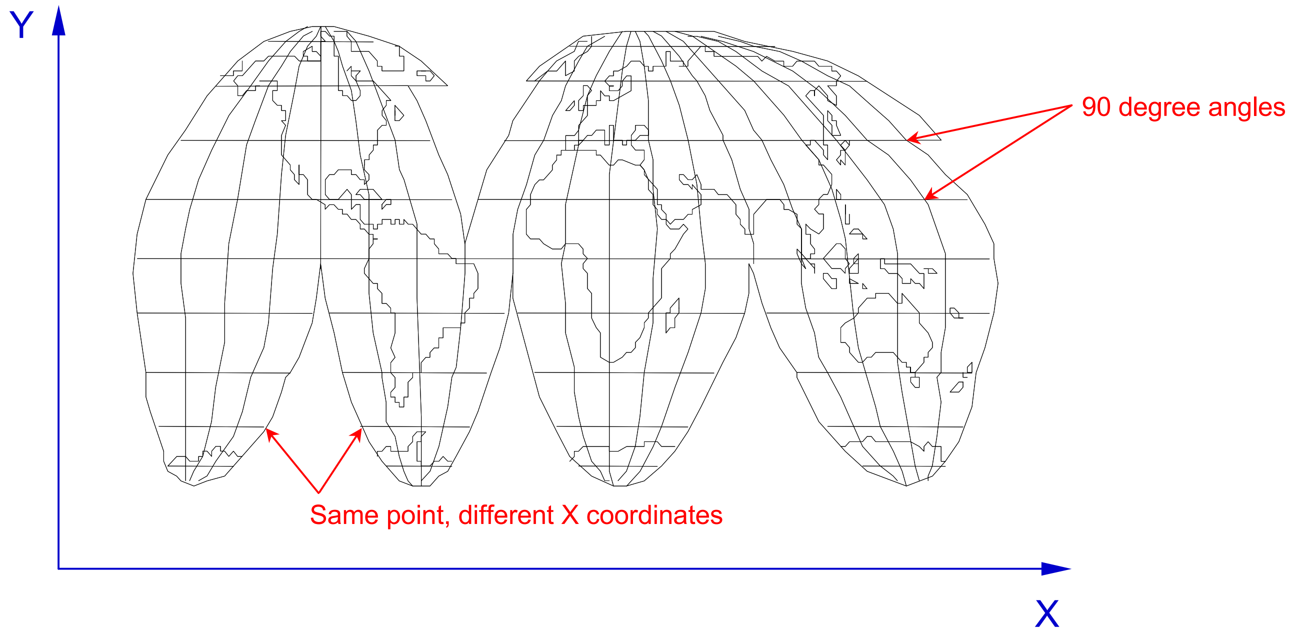


Earth Centered Earth Fixed (ECEF)
Rectangular Coordinate System

Three dimensional position of a point is expressed by x, y, and z

Building a Two-Dimensional Coordinate System

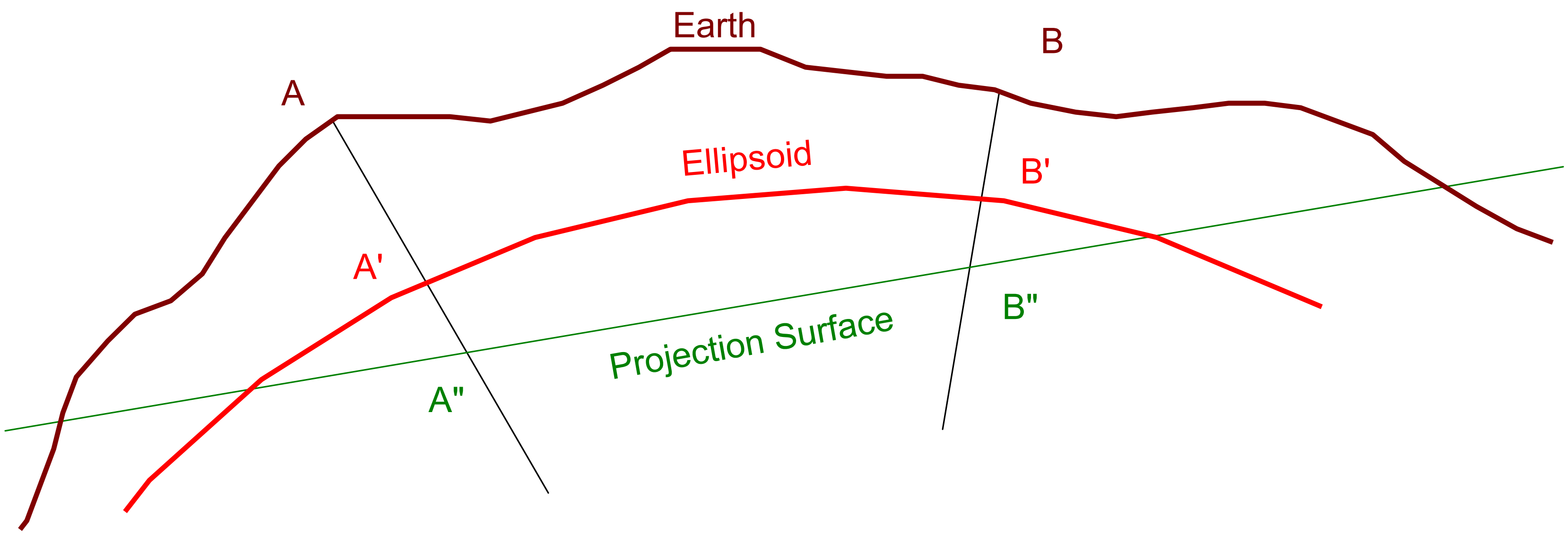
Projecting a 3-D surface into a 2-D surface causes *distortions:*
Linear and Angular



"Orange Peel" Map of the World

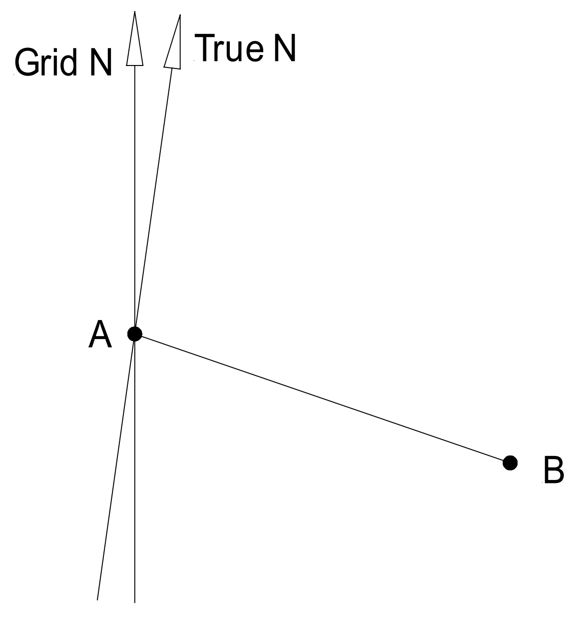
Building a Two-Dimensional Coordinate System

Length distortion occurs when projecting from:
- ground (Earth) to ellipsoid
- ellipsoid to projection surface



Building a Two-Dimensional Coordinate System

Direction distortion occurs because true north lines converge to a point (North Pole)



“Developable” Surface and Projections

A *developable surface* along with fit criteria becomes a projection that can be used to define a coordinate system.

Three commonly used surfaces:

- Plane
- Cylinder
- Cone

The developable surface is placed *tangent* or *secant* to the ellipsoid.

Points are projected from the ellipsoid to the developable surface.

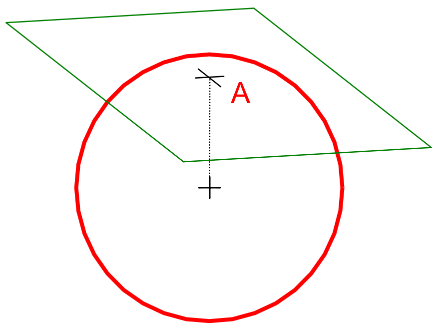
The surface is rolled out flat without “tearing” the surface.

Because a projection is mathematical, distortions introduced can be compensated for mathematically.

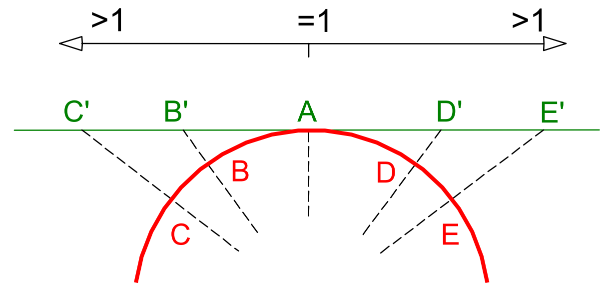
Selecting the type, size, and orientation of the projection allows us to control “maximum” distortions.

Two-Dimensional Rectangular Coordinate Systems

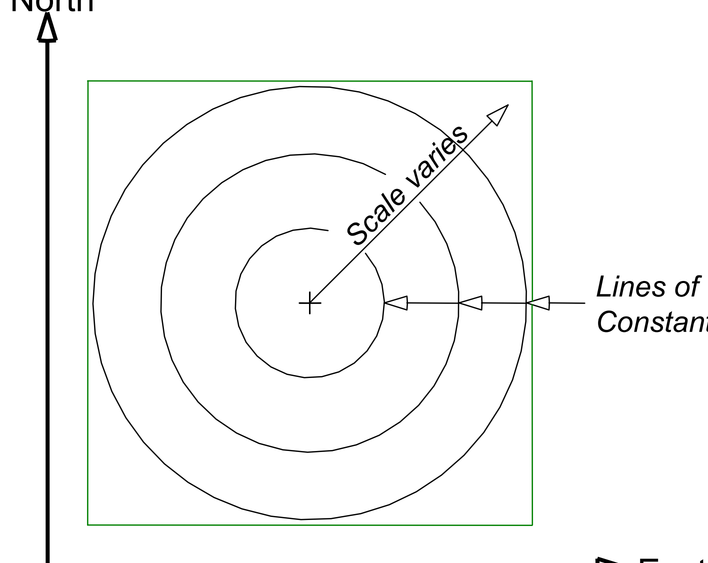
Developable Surface
Plane Projection



Tangent plane



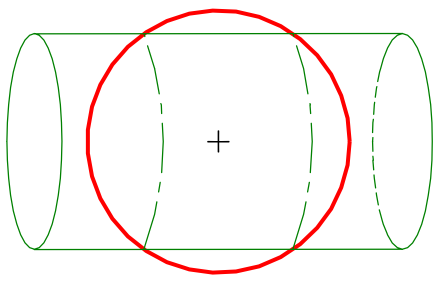
Scale distortions



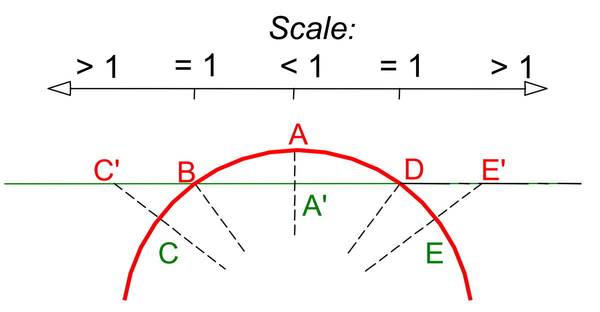
Coordinate system

Two-Dimensional Rectangular Coordinate Systems

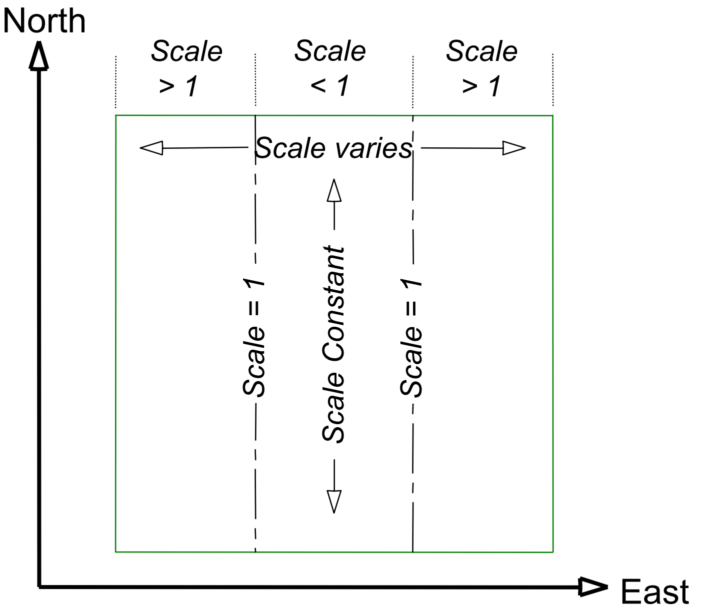
Developable Surface
Cylindrical Projection



Transverse cylinder

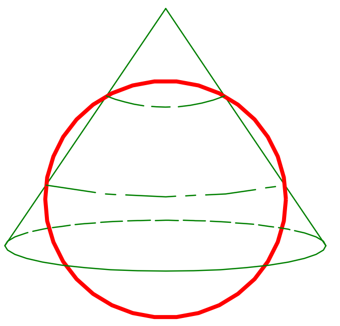


Scale distortions

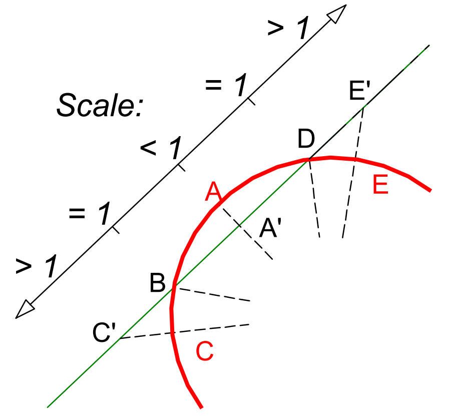


Coordinate system

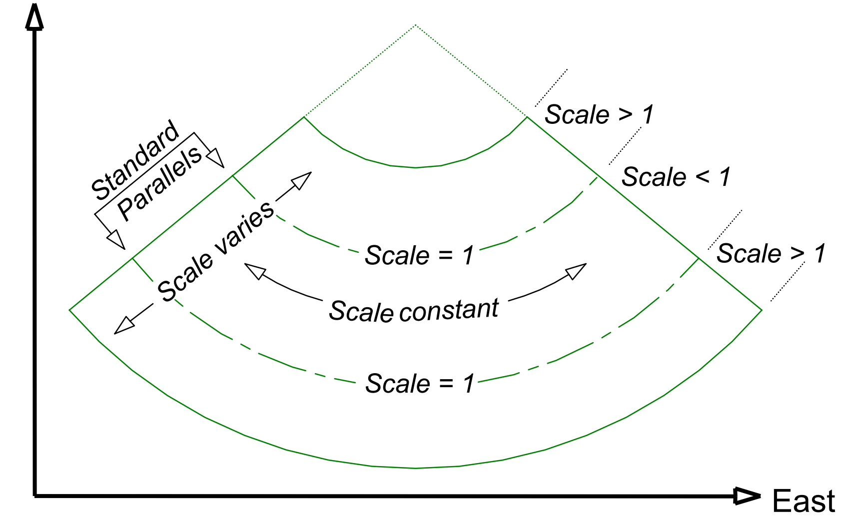
Developable Surface
Conic Projection



Cone



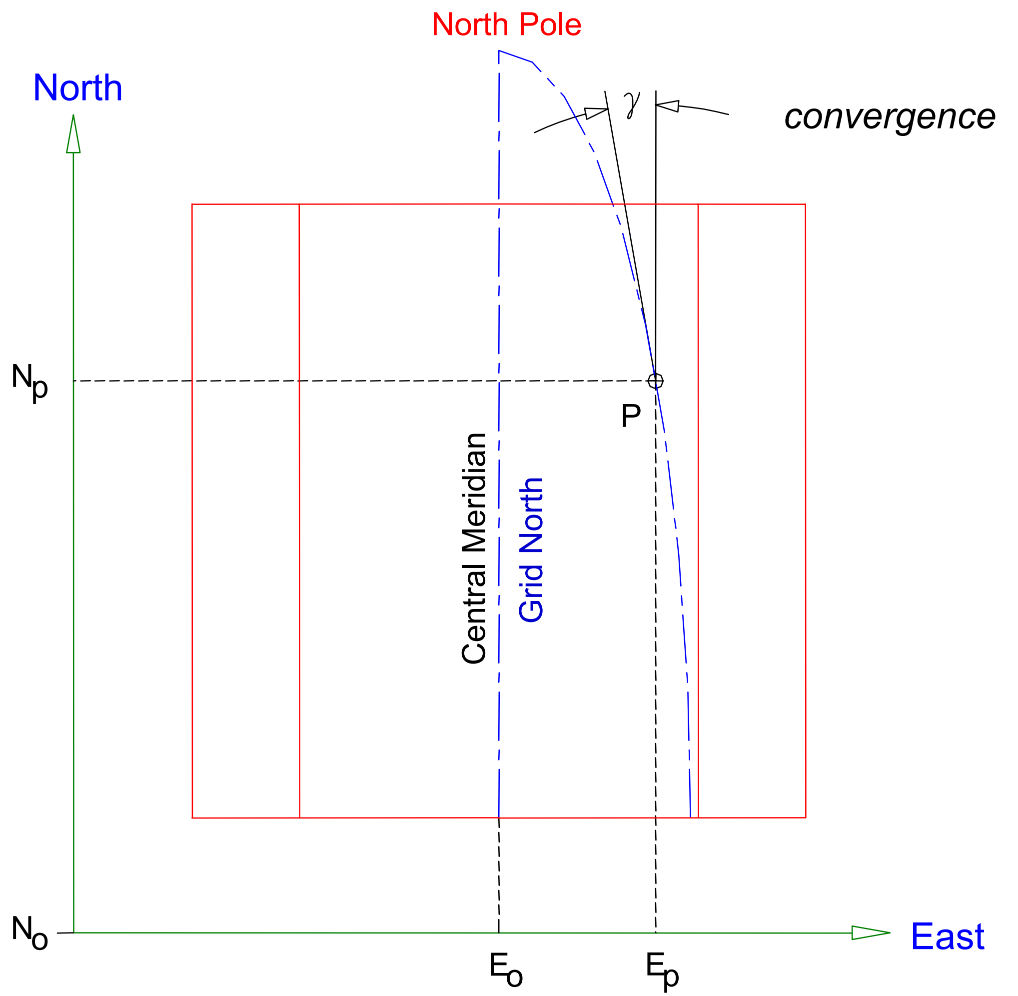
Distortions



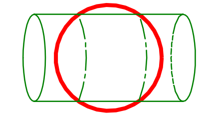
Coordinate system

Two-Dimensional Rectangular Coordinate Systems

Transverse Mercator Cylindrical Projection



Transverse Mercator Cylindrical Projection



Computing Zone/System Constants

Design parameters are used to compute constants for each zone or system.

$$n = \frac{a-b}{a+b} = \frac{f}{2-f}$$

$$r = a(1-n)(1-n^2)\left(1 + \frac{9n^2}{4} + \frac{225n^4}{64}\right)$$

$$u_2 = -\frac{3n}{2} + \frac{9n^3}{16}$$

$$u_4 = \frac{15n^2}{16} - \frac{15n^4}{32}$$

$$u_6 = -\frac{35n^3}{48}$$

$$u_8 = \frac{315n^4}{512}$$

$$U_0 = 2(u_2 - 2u_4 + 3u_6 - 4u_8)$$

$$U_2 = 8(u_4 - 4u_6 + 10u_8)$$

$$U_4 = 32(u_6 - 6u_8)$$

$$U_6 = 128u_8$$

$$v_2 = \frac{3n}{2} - \frac{27n^3}{32}$$

$$v_4 = \frac{21n^2}{16} - \frac{55n^4}{32}$$

$$v_6 = \frac{151n^3}{96}$$

$$v_8 = \frac{1097n^4}{512}$$

$$V_0 = 2(v_2 - 2v_4 + 3v_6 - 4v_8)$$

$$V_2 = 8(v_4 - 4v_6 + 10v_8)$$

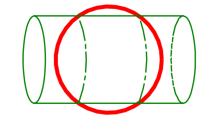
$$V_4 = 32(v_6 - 6v_8)$$

$$V_6 = 128v_8$$

$$\omega_o = \phi_o + \sin\phi_o \cos\phi_o \left(U_0 + U_2\cos^2\phi_o + U_4\cos^4\phi_o + U_6\cos^6\phi_o\right)$$

$$S_o = k_o\omega_o r$$

Transverse Mercator Cylindrical Projection



Direct Conversion Geodetic to grid coordinates

$$L = (\lambda - \lambda_o)\cos\phi$$

$$\omega = \phi + \sin\phi\cos\phi\left(U_0 + U_2\cos^2\phi + U_4\cos^4\phi + U_6\cos^6\phi\right)$$

$$S = k_o\omega r$$

$$t = \tan\phi$$

$$\eta^2 = e'^2\cos^2\phi$$

$$R = \frac{k_o a}{\left(1 - e^2\sin^2\phi\right)^{1/2}}$$

$$A_1 = -R$$

$$A_2 = \frac{1}{2}Rt$$

$$A_3 = \frac{1}{6}\left(1 - t^2 + \eta^2\right)$$

$$A_4 = \frac{1}{12}\left[5 - t^2 + \eta^2\left(9 + 4\eta^2\right)\right]$$

$$A_5 = \frac{1}{120}\left[5 - 18t^2 + t^4 + \eta^2\left(14 - 58t^2\right)\right]$$

$$A_6 = \frac{1}{360}\left[61 - 58t^2 + t^4 + \eta^2\left(270 - 330t^2\right)\right]$$

$$A_7 = \frac{1}{5040}\left(61 - 479t^2 + 179t^4 - t^6\right)$$

$$N = S - S_o + N_o + A_2L^2\left[1 + L^2\left(A_4 + A_6L^2\right)\right]$$

$$E = E_o + A_1L\left[1 + L^2\left(A_3 + L^2\left(A_5 + A_7L^2\right)\right)\right]$$

$$C_1 = -t$$

$$C_3 = \frac{1}{3}\left(1 + 3\eta^2 + 2\eta^4\right)$$

$$C_5 = \frac{1}{15}\left(2 - t^2\right)$$

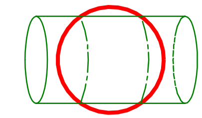
$$F_2 = \frac{1}{2}\left(1 + \eta^2\right)$$

$$F_4 = \frac{1}{12}\left[5 - 4t^2 + \eta^2\left(9 - 24t^2\right)\right]$$

$$\gamma = C_1L\left[1 + L^2\left(C_3 + C_5L^2\right)\right]$$

$$k = k_o\left[1 + F_2L^2\left(1 + F_4L^2\right)\right]$$

Transverse Mercator Cylindrical Projection



Inverse Conversion Grid to geodetic coordinates.

$$\omega = \frac{\left(N - N_o + S_o\right)}{k_o r}$$

$$\phi_f = \omega + \left(\sin\omega\cos\omega\right)\left(V_0 + V_2\cos^2\omega + V_4\cos^4\omega + V_6\cos^6\omega\right)$$

$$t_f = \tan\phi_f$$

$$\eta_f^{\,2} = e'^2\cos^2\phi_f$$

$$R_f = \frac{k_o a}{\left(1 - e^2\sin^2\phi_f\right)^{1/2}}$$

$$Q = \frac{\left(E - E_o\right)}{R_f}$$

$$B_2 = -\frac{1}{2}t_f\left(1 + \eta_f^{\,2}\right)$$

$$B_3 = -\frac{1}{6}\left(1 + 2t_f^{\,2} + \eta_f^{\,2}\right)$$

$$B_4 = -\frac{1}{12}\left[5 + 3t_f^{\,2} + \eta_f^{\,2}\left(1 - 9t_f^{\,2}\right) - 4\eta_f^{\,4}\right]$$

$$B_5 = \frac{1}{120}\left[5 + 28t_f^{\,2} + 24t_f^{\,4} + \eta_f^{\,2}\left(6 + 8t_f^{\,2}\right)\right]$$

$$B_6 = \frac{1}{360}\left[61 + 90t_f^{\,2} + 45t_f^{\,4} + \eta_f^{\,2}\left(46 - 252t_f^{\,2} - 90t_f^{\,4}\right)\right]$$

$$B_7 = -\frac{1}{5040}\left(61 + 662t_f^{\,2} + 1320t_f^{\,4} + 720t_f^{\,6}\right)$$

$$L = Q\left[1 + Q^2\left(B_3 + Q^2\left(B_5 + B_7Q^2\right)\right)\right]$$

$$\phi = \phi_f + B_2Q^2\left[1 + Q^2\left(B_4 + B_6Q^2\right)\right]$$

$$\lambda = \lambda_o - \frac{L}{\cos\phi_f}$$

$$D_1 = t_f$$

$$D_3 = -\frac{1}{3}\left(1 + t_f^{\,2} - \eta_f^{\,2} - 2\eta_f^{\,4}\right)$$

$$D_5 = \frac{1}{15}\left(2 + 5t_f^{\,2} + 3t_f^{\,4}\right)$$

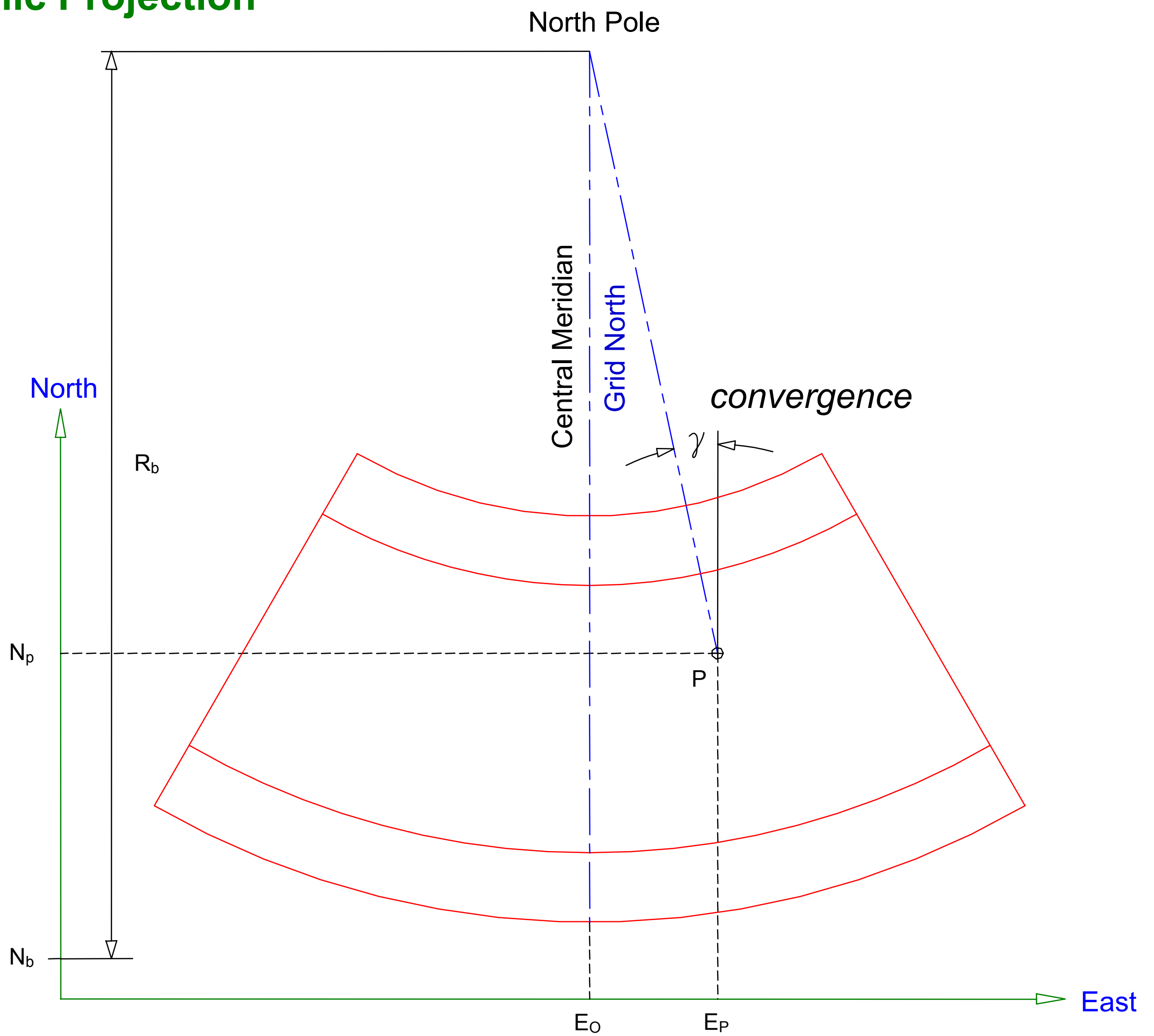
$$G_2 = \frac{1}{2}\left(1 + \eta_f^{\,2}\right)$$

$$G_4 = \frac{1}{12}\left(1 + 5\eta_f^{\,2}\right)$$

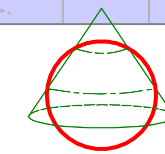
$$\gamma = D_1Q\left[1 + Q^2\left(D_3 + D_5Q^2\right)\right]$$

$$k = k_o\left[1 + G_2Q^2\left(1 + G_4Q^2\right)\right]$$

Lambert Conic Projection



Two-Dimensional Rectangular Coordinate Systems



Lambert Conic Projection

Computing Zone/System Constants

Design parameters are used to compute constants for each zone or system.

$$Q_s = \frac{1}{2}\left[ln\left(\frac{1+\sin\phi_s}{1-\sin\phi_s}\right) - e\ ln\left(\frac{1+e\sin\phi_s}{1-e\sin\phi_s}\right)\right]$$

$$W_s = \left(1-e^2\sin^2\phi_s\right)^{1/2}$$

$$\sin\phi_o = \frac{ln\left(\frac{W_n\cos\phi_s}{W_s\cos\phi_n}\right)}{Q_n - Q_s}$$

$$K = \frac{a\cos\phi_s\exp\left(Q_s\sin\phi_o\right)}{W_s\sin\phi_o} = \frac{a\cos\phi_n\exp\left(Q_n\sin\phi_o\right)}{W_n\sin\phi_o}$$

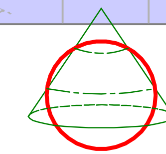
$$R_b = \frac{K}{\exp\left(Q_b\sin\phi_o\right)}$$

$$R_0 = \frac{K}{\exp\left(Q_o\sin\phi_o\right)}$$

$$k_o = \frac{\left(W_o\tan\phi_o R_o\right)}{a}$$

$$N_o = R_b + N_b - R_o$$

Two-Dimensional Rectangular Coordinate Systems



Lambert Conic Projection

Direct Conversion Geodetic to grid coordinates

$$Q = \frac{1}{2}\left[ln\left(\frac{1+\sin\phi}{1-\sin\phi}\right) - e\ ln\left(\frac{1+e\sin\phi}{1-e\sin\phi}\right)\right]$$

$$R = \frac{K}{\exp\left(Q\sin\phi_o\right)}$$

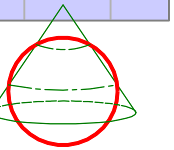
$$\gamma = \left(\lambda_o - \lambda\right)\sin\phi_o$$

$$N = R_b + N_b - R\cos\gamma$$

$$E = E_o + R\sin\gamma$$

$$k = \left(1 - e^2\sin^2\phi\right)^{1/2}\frac{\left(R\sin\phi_o\right)}{\left(a\cos\phi\right)}$$

Two-Dimensional Rectangular Coordinate Systems



Lambert Conic Projection

Inverse Conversion Grid to geodetic coordinates.

$$R' = R_b - N + N_b$$

$$E' = E - E_o$$

$$\gamma = \tan^{-1}\left(E'/R'\right)$$

$$\lambda = \lambda_o - \left(\gamma / \sin\phi_o\right)$$

$$R = \left(R'^2 + E'^2\right)^{1/2}$$

$$Q = \frac{ln\left(K/R\right)}{\sin\phi_o}$$

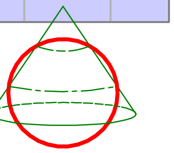
$$f_1 = \frac{1}{2}\left[ln\left(\frac{1+\sin\phi}{1-\sin\phi}\right) - e\, ln\left(\frac{1+e\sin\phi}{1-e\sin\phi}\right) \right] - Q$$

$$f_2 = \left(\frac{1}{1-\sin^2\phi}\right) - \left(\frac{e^2}{1-e^2\sin^2\phi}\right)$$

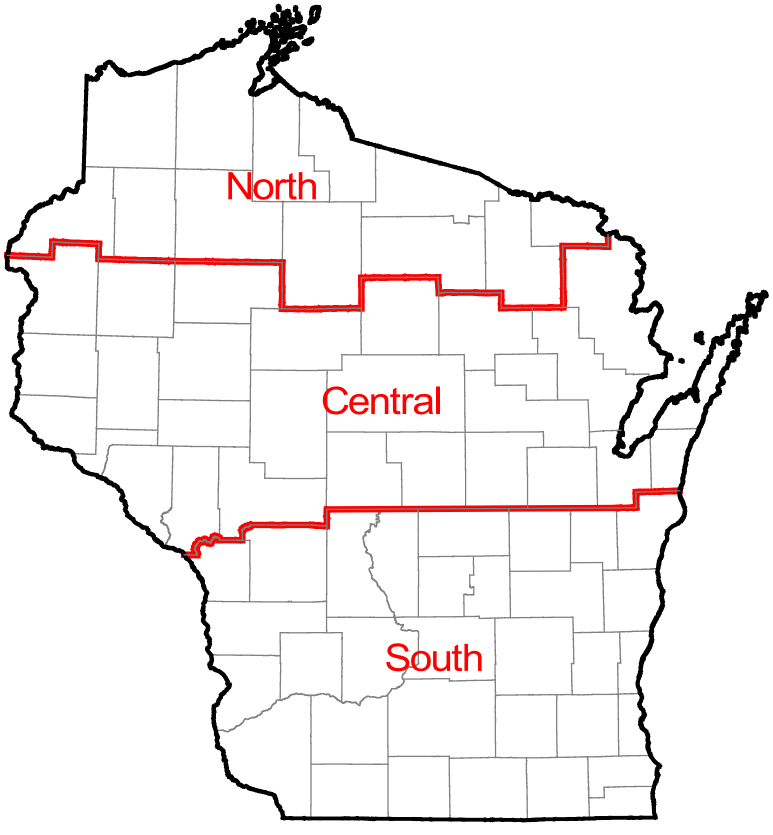
$$\sin\phi = \frac{\exp(2Q)-1}{\exp(2Q)+1}$$

$$k = \left(1-e^2\sin^2\phi\right)^{1/2}\frac{\left(R\sin\phi_o\right)}{\left(a\cos\phi\right)}$$

Formal Coordinate Systems in Wisconsin

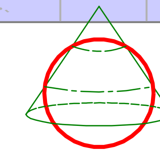


Wisconsin State Plane Coordinate (SPC) Zones
NAD 27 and NAD 83

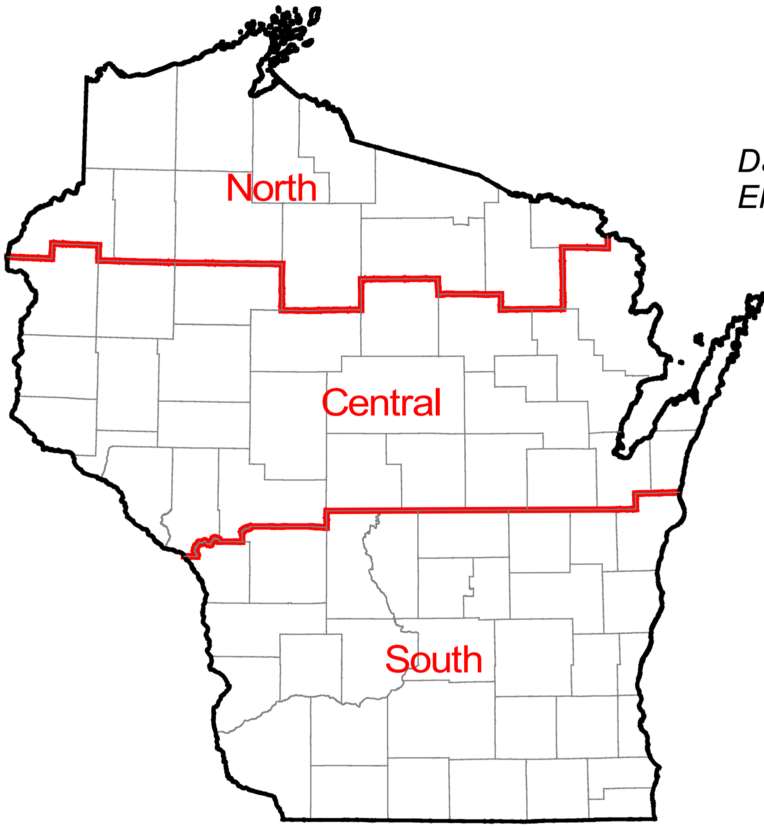


Three Lambert Conic Projection Zones

Maximum scale distortion
(ellipsoid to projection): 1/10,000



Wisconsin State Plane Coordinate (SPC) Zones
NAD 27



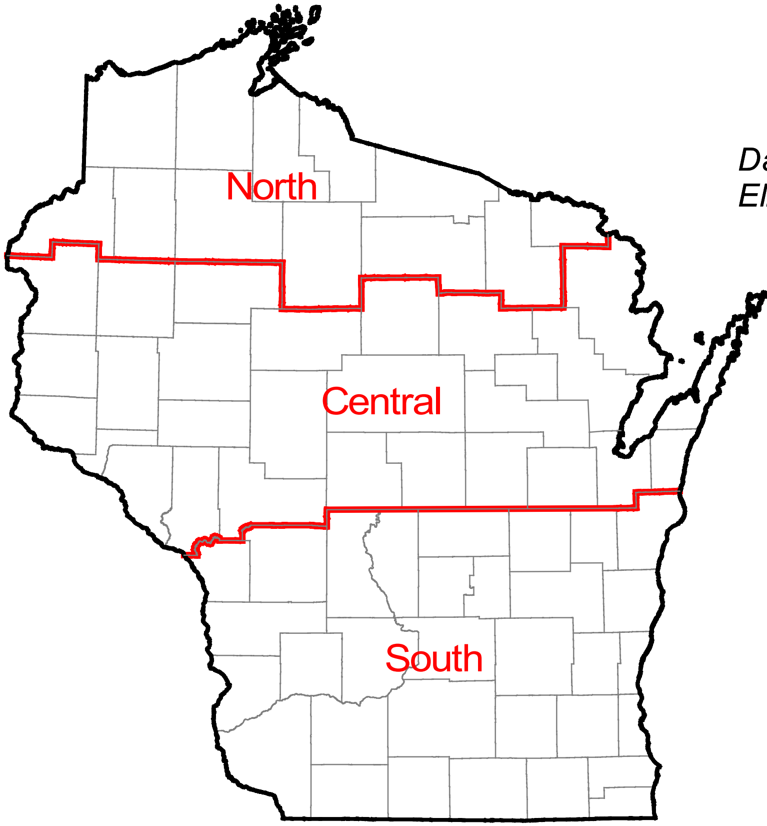
Datum: NAD 27
Ellipsoid: Clarke 1866

	Zone	*North*	*Central*	*South*
	Code	4801	4802	4803
	South Std Par	45°34' N	44°15' N	42°44' N
	North Std Par	46°46' N	45°30' N	44°04' N
	Central Meridian	90°00' W	90°00' W	90°00' W
	Latitude of Origin	45°10' N	43°50' N	42°00' N
N_b	Origin Northing	0 ft	0 ft	0 ft
E_o	Origin Easting	2,000,000 ft	2,000,000 ft	2,000,000 ft

NAD 27 uses the US Survey foot (39.37 inches = 1 meter, exact) as the defining linear unit.

Formal Coordinate Systems in Wisconsin

Wisconsin State Plane Coordinate (SPC) Zones
NAD 83



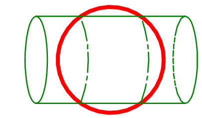
Datum: NAD 83
Ellipsoid: GRS 80

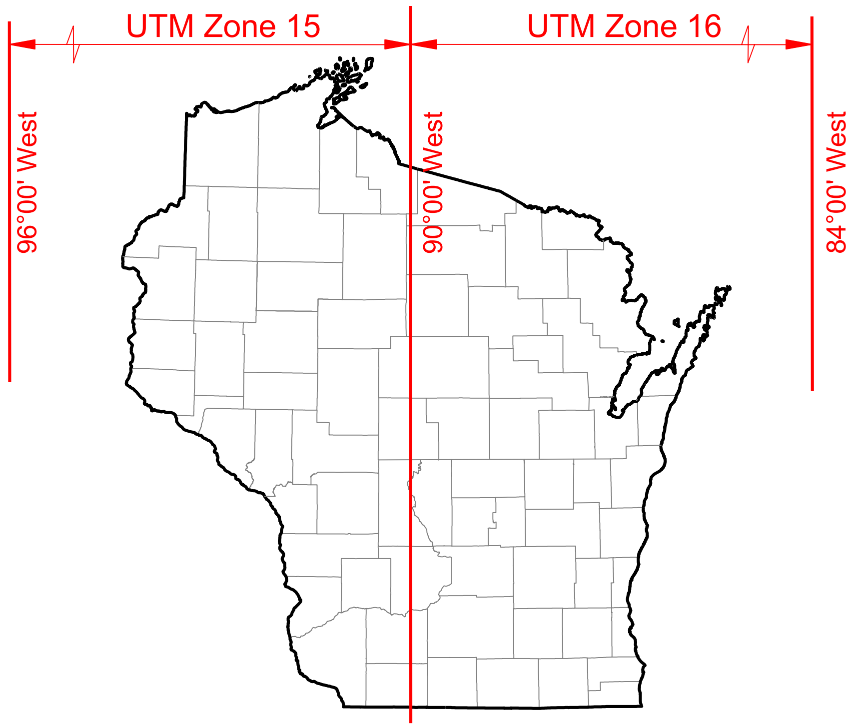
	Zone Code	*North* 4801	*Central* 4802	*South* 4803
	South Std Par	45°34' N	44°15' N	42°44' N
	North Std Par	46°46' N	45°30' N	44°04' N
	Central Meridian	90°00' W	90°00' W	90°00' W
	Latitude of Origin	45°10' N	43°50' N	42°00' N
N_b	Origin Northing	0 m	0 m	0 m
E_o	Origin Easting	600,000 m	600,000 m	600,000 m

NAD 83 datums use the meter as the defining linear unit.

Formal Coordinate Systems in Wisconsin

Universal Transverse Mercator (UTM) Zones
NAD 27 and NAD 83





Maximum scale distortion
(ellipsoid to projection): 1/2,500

Two 6° wide transverse cylindrical zones

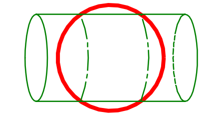
UTM Zones are defined using the same parameters for both NAD 27 and NAD 83 datums:

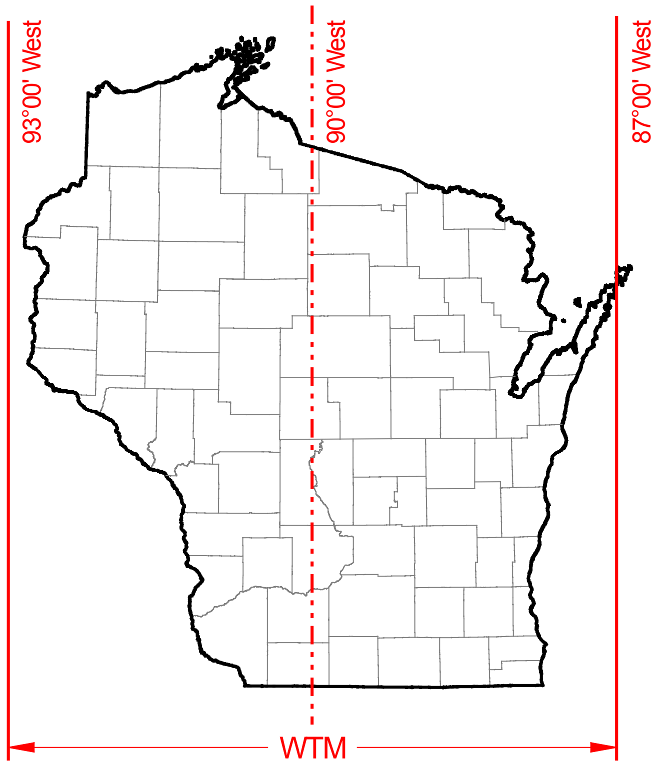
	UTM Zone	*UTM 15N*	*UTM 16N*
	Central Meridian	93°00' W	87°00' W
	Latitude of Origin	0°00' N	0°00' N
N_o	Origin Northing	0 m	0 m
E_o	Origin Easting	500,000 m	500,000 m
k_o	Scale at Cen Mer	0.9996	0.9996

UTM systems use the meter as the defining linear unit.

Formal Coordinate Systems in Wisconsin

Wisconsin Transverse Mercator (WTM) Zone
NAD 27 and NAD 83





Maximum scale distortion
(ellipsoid to projection): 1/2,500

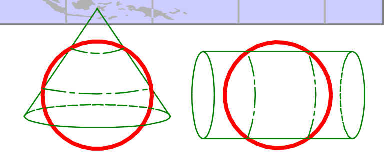
One 6° wide transverse cylindrical zone

WTM is defined for NAD 27 and NAD 83.
A distinct "shift" of approximately 13 miles in northing and easting was introduced to the NAD 83 parameters to more easily distinguish the coordinate values:

		NAD 27	*NAD 83*
	Central Meridian	90°00' W	90°00' W
	Latitude of Origin	0°00' N	0°00' N
N_o	Origin Northing	-4,500,000 m	-4,480,000 m
E_o	Origin Easting	500,000 m	520,000 m
k_o	Scale at Cen Mer	0.9996	0.9996

The WTM system uses the meter as the defining linear unit.

Formal Coordinate Systems in Wisconsin



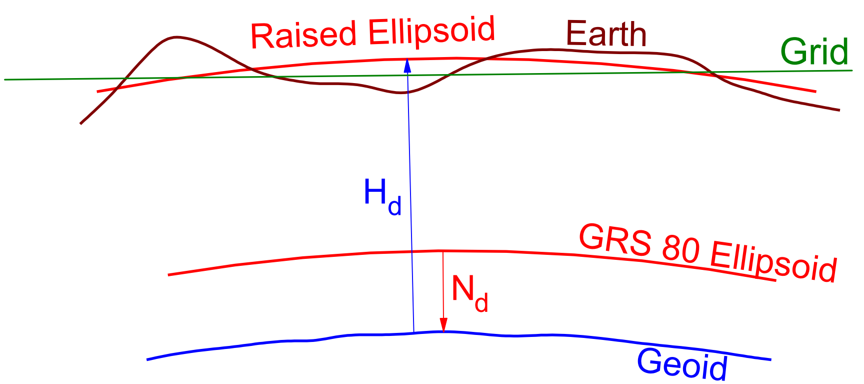
Wisconsin County Coordinate System
NAD 83 (1991)

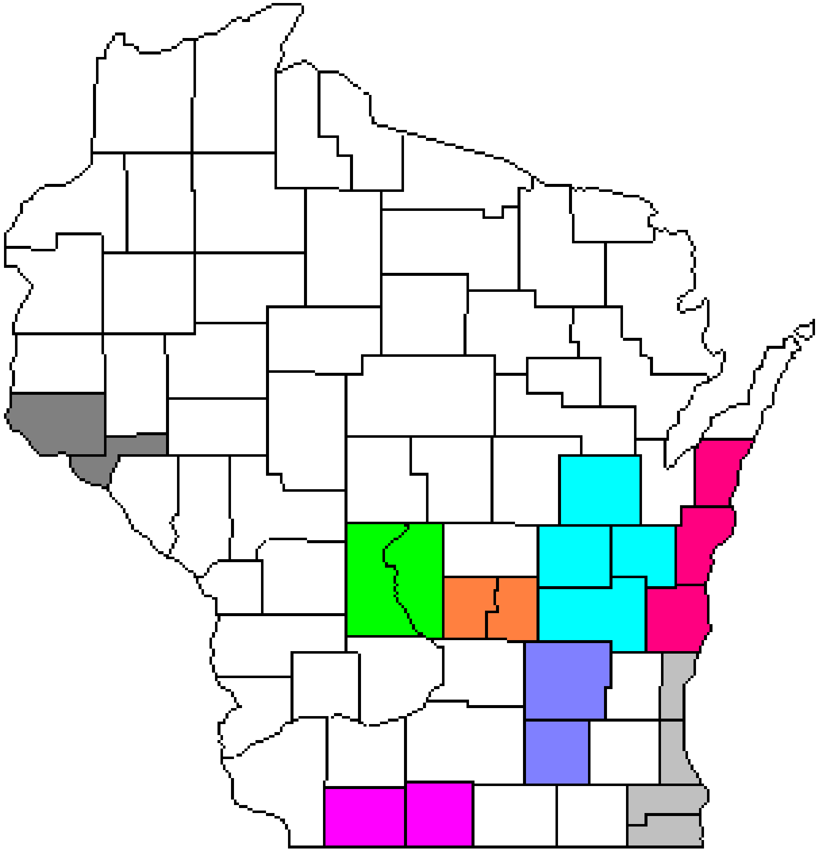
59 systems covering 72 counties

Conic or cylindrical projection

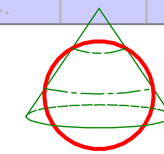
Each uses a "raised" ellipsoid

Maximum ratio: (grid to ground)
  1/30,000 rural
  1/50,000 urban





Formal Coordinate Systems in Wisconsin

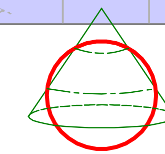


Wisconsin County Coordinate System
NAD 83 (1991)

Conic projections

County	H_d (m)	N_d (m)	λ_o (d.ms)	ϕ_b (d.ms)	E_o (m)	N_b (m)	ϕ_n (d.ms)	ϕ_s (d.ms)
Bayfield	304.801	-30.45	91°09'10"	45°20'00"	228,600.4572	0.0000	46°55'30"	46°24'50"
Burnett	304.800	-26.84	92°27'28"	45°21'50"	64,008.1280	0.0000	46°05'00"	45°21'50"
Chippewa	304.800	-29.26	91°17'40"	44°34'52"	60,045.7201	0.0000	45°08'30"	44°48'50"
Columbia	274.321	-34.99	89°23'40"	42°27'30"	169,164.3383	0.0000	43°35'30"	43°20'00"
Crawford	274.321	-32.29	90°56'20"	42°43'00"	113,690.6274	0.0000	43°20'30"	43°03'30"
Dane	304.801	-34.18	89°25'20"	41°45'00"	247,193.2944	0.0000	43°13'50"	42°54'30"
Eau Claire	274.321	-30.94	91°17'20"	44°02'50"	120,091.4402	0.0000	45°00'50"	44°43'50"
Green	304.801	-33.32	89°50'20"	42°13'30"	170,078.7402	0.0000	42°47'20"	42°29'10"
Green Lake	274.321	-35.72	89°14'30"	43°05'40"	150,876.3018	0.0000	43°56'50"	43°40'00"
Jackson *	304.810	-32.65	90°44'20"	43°47'40"	125,882.6518	0.0000	44°25'10"	44°09'50"
Lafayette	304.801	-33.32	89°50'20"	42°13'30"	170,078.7402	0.0000	42°47'20"	42°29'10"
Langlade	457.201	-34.08	89°02'00"	44°12'25"	198,425.1968	0.0000	45°18'30"	45°00'00"
Marathon	396.240	-32.64	89°46'12"	44°24'20"	74,676.1494	0.0000	45°03'23"	44°44'43"
Marquette	274.321	-35.72	89°14'30"	43°05'40"	150,876.3018	0.0000	43°56'50"	43°40'00"
Monroe	335.281	-33.29	90°38'30"	42°54'10"	204,521.2091	0.0000	44°09'40"	43°50'20"
Oneida	487.700	-30.84	89°32'40"	45°11'10"	70,104.1402	0.0000	45°50'30"	45°34'00"
Pepin	274.321	-30.05	92°13'40"	43°51'43"	167,640.3353	0.0000	44°45'00"	44°31'20"
Pierce	274.321	-30.05	92°13'40"	43°51'43"	167,640.3353	0.0000	44°45'00"	44°31'20"
Portage	341.377	-34.00	89°30'00"	43°58'00"	56,388.1128	0.0000	44°38'60"	44°11'00"

* These parameters are for the WCCS Jackson County System.

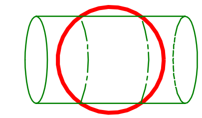


Wisconsin County Coordinate System
NAD 83 (1991)

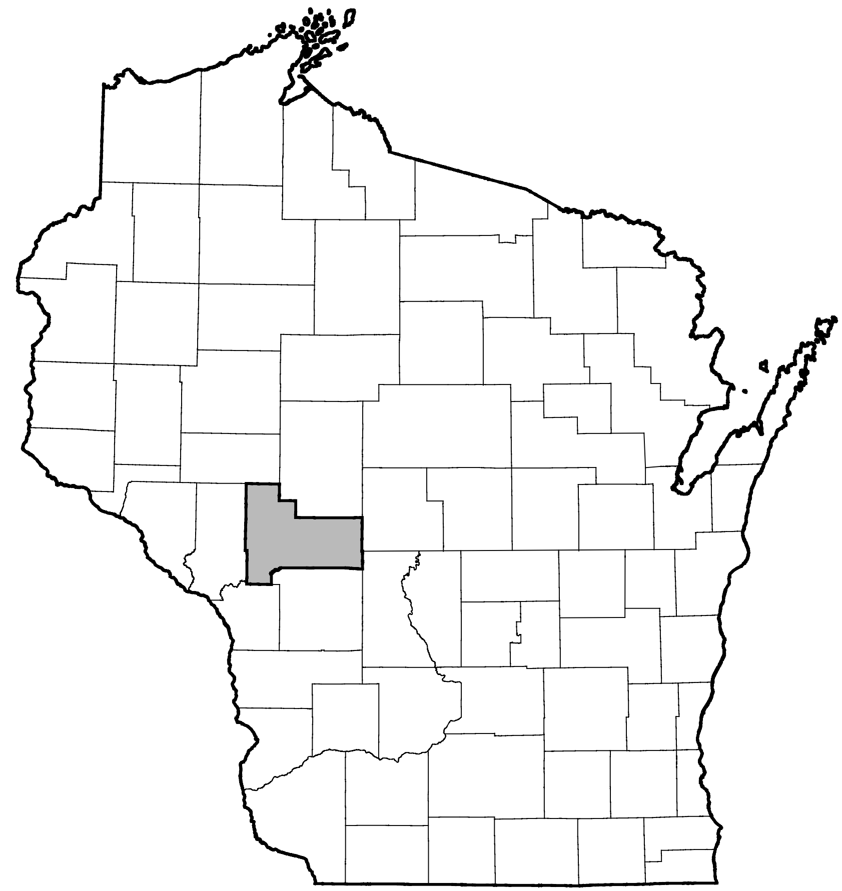
Conic projections

County	H_d (m)	N_d (m)	λ_o (d.ms)	ϕ_b (d.ms)	E_o (m)	N_b (m)	ϕ_n (d.ms)	ϕ_s (d.ms)
Richland	304.801	-33.71	90°25'50"	42°06'50"	202,387.6048	0.0000	43°30'10"	43°08'30"
Sawyer	476.721	-29.27	91°07'00"	44°48'50"	216,713.2334	0.0000	46°04'50"	45°43'10"
Taylor	426.721	-30.80	90°29'00"	44°12'30"	187,147.5743	0.0000	45°18'00"	45°03'20"
Vernon	304.801	-32.86	90°47'00"	43°08'50"	222,504.4450	0.0000	43°41'00"	43°28'00"
Vilas	518.161	-30.99	89°29'20"	45°37'30"	134,417.0688	0.0000	46°13'30"	45°55'50"
Walworth	274.321	-33.91	88°32'30"	41°40'10"	232,562.8651	0.0000	42°45'00"	42°35'20"
Washburn	365.761	-28.17	91°47'00"	44°15'60"	234,086.8681	0.0000	46°09'00"	45°46'20"
Waushara	304.801	-35.83	89°14'30"	43°42'30"	120,091.4402	0.0000	44°15'10"	43°58'30"
Wood	335.281	-34.63	90°00'00"	43°09'05"	208,483.6170	0.0000	44°32'40"	44°10'50"

Formal Coordinate Systems in Wisconsin

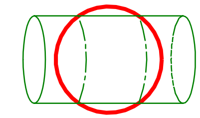


Wisconsin County Coordinate System
NAD 83 (1991)



The *Jackson County Official Projection* does not use a raised enlarged ellipsoid and is instead referenced to the GRS 80 ellipsoid.
It is based on a transverse cylindric projection:

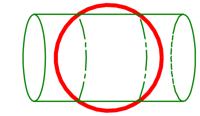
	Central Meridian	90°50'39.46747" W
	Latitude of Origin	44°15'12.00646" N
N_o	Origin Northing	25,000.000 m
E_o	Origin Easting	27,000.000 m
k_o	Scale at Cen Mer	1.00003 53000



Wisconsin County Coordinate System
NAD 83 (1991)

Cylindrical projections

County	H_d (m)	N_d (m)	λ_o (d.ms)	ϕ_o (d.ms)	E_o (m)	N_o (m)	k_o
Adams	274.321	-35.05	90°00'00"	43°22'00"	147,218.6945	0.0000	0.99999 9000
Ashland	365.760	-30.84	90°37'20"	45°42'22"	172,821.9456	0.0000	0.99999 7000
Barron	365.761	-29.83	91°51'00"	45°08'00"	93,150.0000	0.0000	0.99999 6000
Brown	35.800	-35.80	88°00'00"	43°00'00"	31,600.0000	4,600.0000	1.00002 0000
Buffalo	274.321	-30.33	91°47'50"	43°28'53"	175,260.3505	0.0000	1.00000 0000
Calumet	243.840	-35.75	88°30'00"	42°43'10"	244,754.8895	0.0000	0.99999 6000
Clark	365.761	-32.36	90°42'30"	43°36'00"	199,949.1998	0.0000	0.99999 4000
Dodge	274.321	-34.51	88°46'30"	41°28'20"	263,347.7267	0.0000	0.99999 7000
Door	213.360	-36.44	87°16'20"	44°24'00"	158,801.1176	0.0000	0.99999 1000
Douglas	304.800	-26.87	91°55'00"	45°53'00"	59,131.3183	0.0000	0.99999 4968
Dunn	304.801	-28.78	91°53'40"	44°24'30"	51,816.1040	0.0000	0.99999 7730
Florence	426.721	-32.87	88°08'30"	45°26'20"	133,502.6670	0.0000	0.99999 3500
Fond du Lac	243.840	-35.75	88°30'00"	42°43'10"	244,754.8895	0.0000	0.99999 6000
Forest	487.681	-33.16	88°38'00"	44°00'20"	275,844.5516	0.0000	0.99999 6000
Grant	274.321	-32.44	90°48'00"	41°24'40"	242,316.4847	0.0000	0.99999 7000
Iowa	304.801	-33.76	90°09'40"	42°32'20"	113,081.0262	0.0000	0.99999 7000
Iron	487.681	-30.39	90°15'20"	45°26'00"	220,980.4420	0.0000	0.99999 6000
Jefferson	274.321	-34.51	88°46'30"	41°28'20"	263,347.7267	0.0000	0.99999 7000
Juneau	274.321	-35.05	90°00'00"	43°22'00"	147,218.6945	0.0000	0.99999 9000
Kenosha	213.360	-34.66	87°53'40"	42°13'00"	185,928.3719	0.0000	0.99999 8000
Kewaunee	182.880	-34.02	87°33'00"	43°16'00"	79,857.7600	0.0000	1.00000 0000
LaCrosse	274.321	-32.02	91°19'00"	43°27'04"	130,454.6609	0.0000	0.99999 4000



Wisconsin County Coordinate System
NAD 83 (1991)

Cylindrical projections

County	H_d (m)	N_d (m)	λ_o (d.ms)	ϕ_o (d.ms)	E_o (m)	N_o (m)	k_o
Lincoln	426.721	-31.90	89°44'00"	44°50'40"	116,129.0323	0.0000	0.99999 8000
Manitowoc	182.880	-34.02	87°33'00"	43°16'00"	79,857.7600	0.0000	1.00000 0000
Marinette	274.321	-35.28	87°42'40"	44°41'30"	238,658.8774	0.0000	0.99998 6000
Menominee	304.801	-35.20	88°25'00"	44°43'00"	105,461.0109	0.0000	0.99999 4000
Milwaukee	213.360	-34.66	87°53'40"	42°13'00"	185,928.3719	0.0000	0.99999 8000
Oconto	243.840	-35.42	87°54'30"	44°23'50"	182,880.3658	0.0000	0.99999 1000
Outagamie	243.840	-35.75	88°30'00"	42°43'10"	244,754.8895	0.0000	0.99999 6000
Ozaukee	213.360	-34.66	87°53'40"	42°13'00"	185,928.3719	0.0000	0.99999 8000
Polk	304.801	-28.13	92°38'00"	44°39'40"	141,732.2834	0.0000	1.00000 0000
Price	457.201	-30.31	90°29'20"	44°33'20"	227,990.8560	0.0000	0.99999 8000
Racine	213.360	-34.66	87°53'40"	42°13'00"	185,928.3719	0.0000	0.99999 8000
Rock	274.321	-33.65	89°04'20"	41°56'40"	146,304.2926	0.0000	0.99999 6000
Rusk	365.761	-30.01	91°04'00"	43°55'10"	250,546.1011	0.0000	0.99999 7000
Sauk	304.801	-34.52	89°54'00"	42°49'10"	185,623.5713	0.0000	0.99999 5000
Shawano	304.801	-35.75	88°36'20"	44°02'10"	262,433.3249	0.0000	0.99999 0000
Sheboygan	182.880	-34.02	87°33'00"	43°16'00"	79,857.7600	0.0000	1.00000 0000
St. Croix	304.801	-29.29	92°38'00"	44°02'10"	165,506.7310	0.0000	0.99999 5000
Trempealeau	274.321	-31.23	91°22'00"	43°09'40"	256,946.9138	0.0000	0.99999 8000
Washington	304.801	-34.66	88°03'50"	42°55'05"	120,091.4402	0.0000	0.99999 5000
Waukesha	274.321	-34.45	88°13'30"	42°34'10"	208,788.4176	0.0000	0.99999 7000
Waupaca	274.321	-36.07	88°49'00"	43°25'13"	185,013.9701	0.0000	0.99999 6000
Winnebago	243.840	-35.75	88°30'00"	42°43'10"	244,754.8895	0.0000	0.99999 6000

WCCS: Emerging Issues & Solutions

- Al Vonderohe

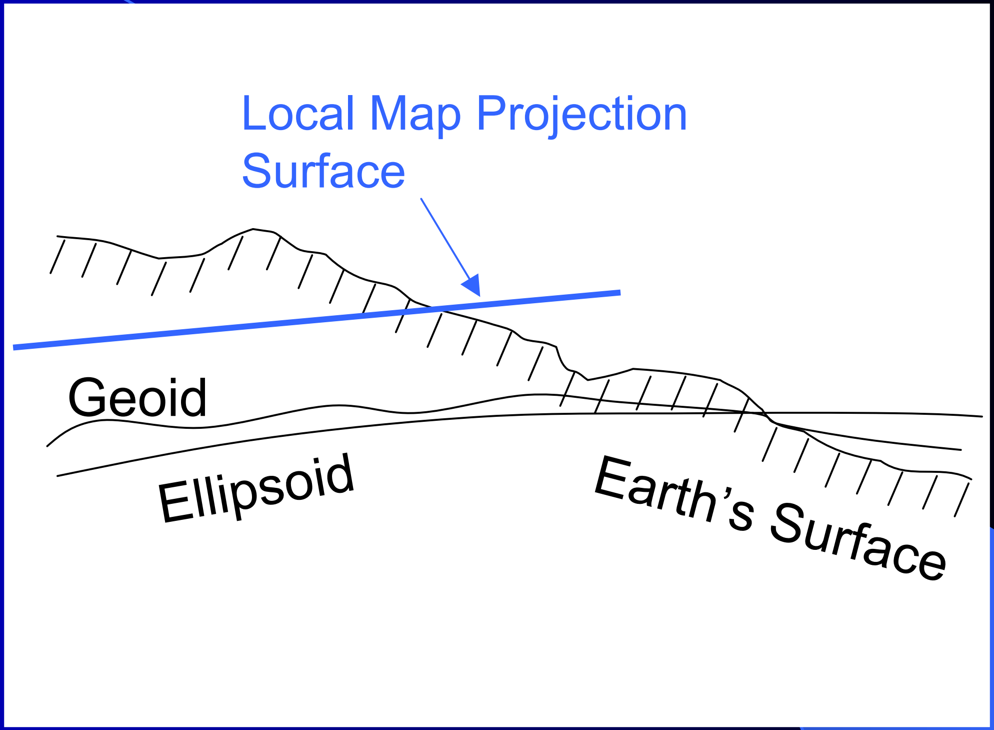
Emerging Issue

- Enlarging the ellipsoid has the mathematical effect of modifying the underlying geodetic datum.
- This has caused difficulties in both the vendor and user communities.
  - Vendors want to support WCCS, but there is complexity.
  - Most of the user community doesn't have a clue about datums and map projections.

WLIA Task Force

- The WLIA Task Force on Wisconsin Coordinate Systems was formed early this year to address this and other issues associated with location referencing in Wisconsin.
- A question that emerged:
- Can the WCCS be re-designed so that:
  1. There is no need to change the ellipsoid from GRS 80. That is, there will be one datum for all projections.
  2. Coordinate differences between the existing and re-designed systems will be within negligible bounds. In this way, legacy databases and records will not have to be modified.

- Leave the ellipsoid where it is and enlarge only the map projection surface.
- This way, the ellipsoid factor and the scale factor are nearly inverses of one another and their product = 1.



Approach to Lambert Re-Design

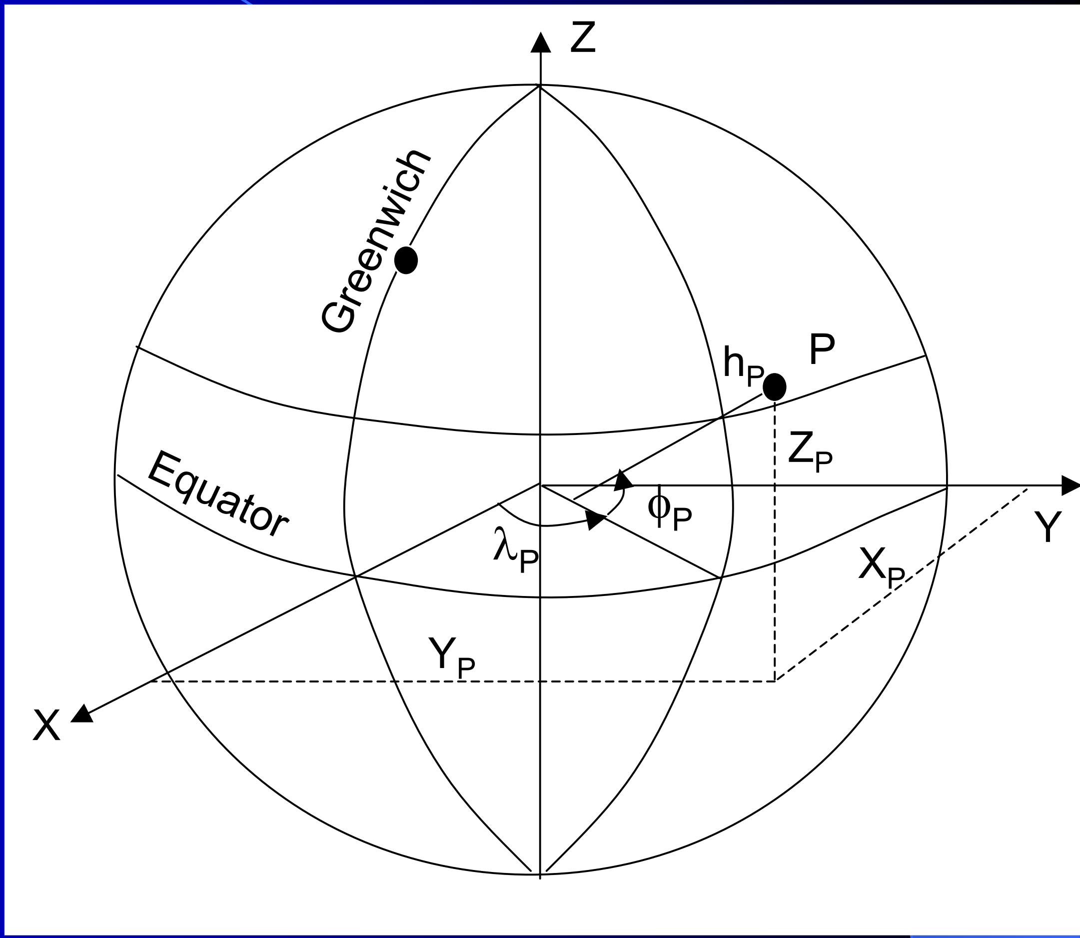
- Two strategies:
  1. Make the original and re-designed map projection surfaces be identical in three-dimensional space.
     - This will cause the latitude of the central parallel (ϕ_0) to change.
     - Challenge: Finding ϕ_0.
  2. Hold ϕ_0 constant.
     - This will cause the original and re-designed map projection surfaces to be dissimilar.
     - Challenge: Finding k_0.

Approach to Strategy 1

- Work in geocentric coordinates (3D rectangular).
- Use analytical geometry.
- Find equations of the line that is the projection of the central meridian.
- Find the point of tangency between GRS 80 ellipsoid and a line parallel with the above line.
- Convert X,Y,Z of this point to ϕ,λ,h. ϕ is the latitude of the central parallel.

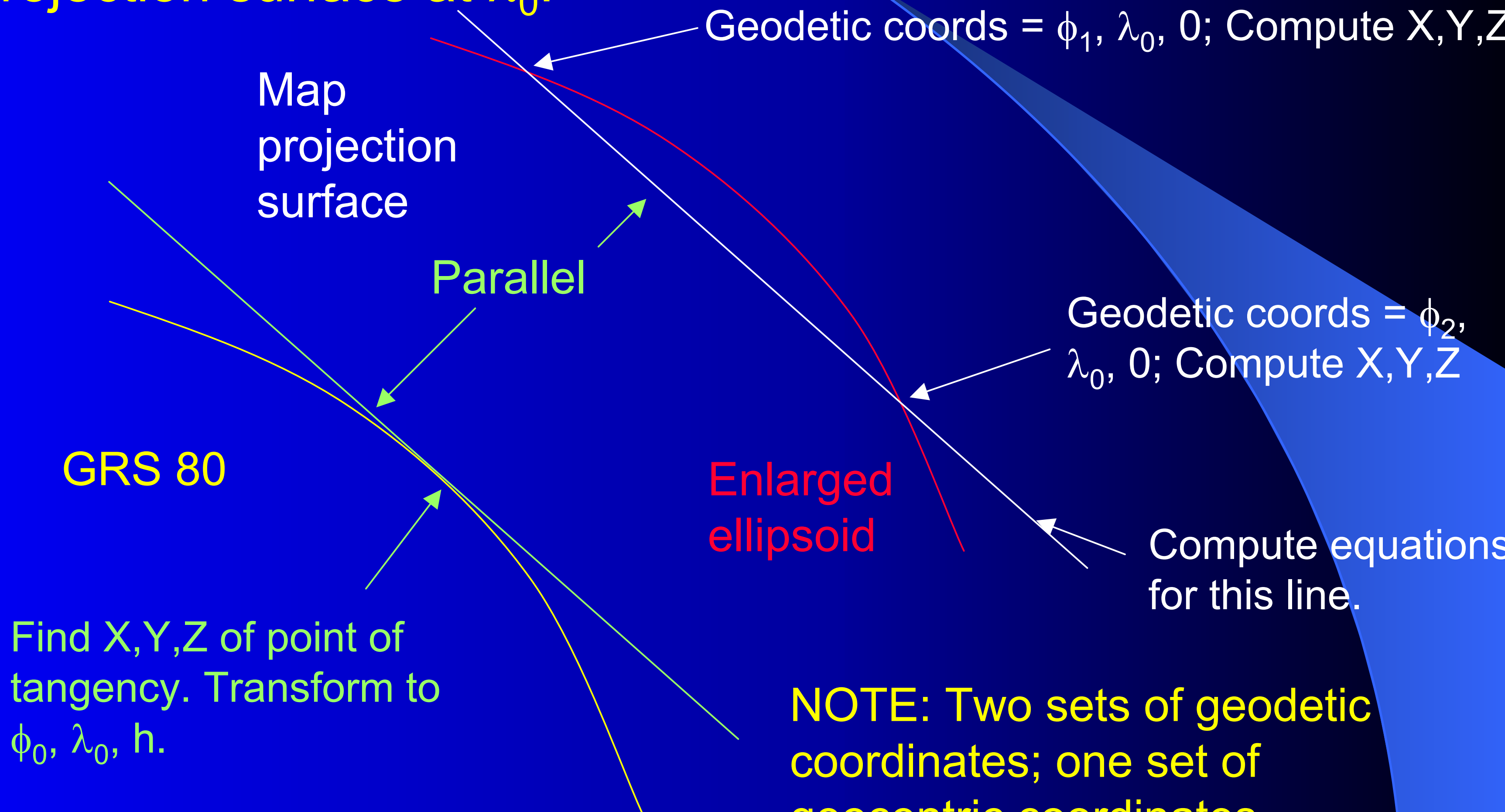
Geocentric / Geodetic Coordinates

- Geocentric coordinates are based upon a 3D right-handed system with origin at ellipsoid center, XY plane is the equatorial plane, +X axis passes through λ = 08, +Y axis passes through λ = 908E.
- For any point, there are direct and inverse transformations between X,Y,Z and φ,λ,h.



Approach to Strategy 1

Profile through GRS80, enlarged ellipsoid, and original map projection surface at λ_0:



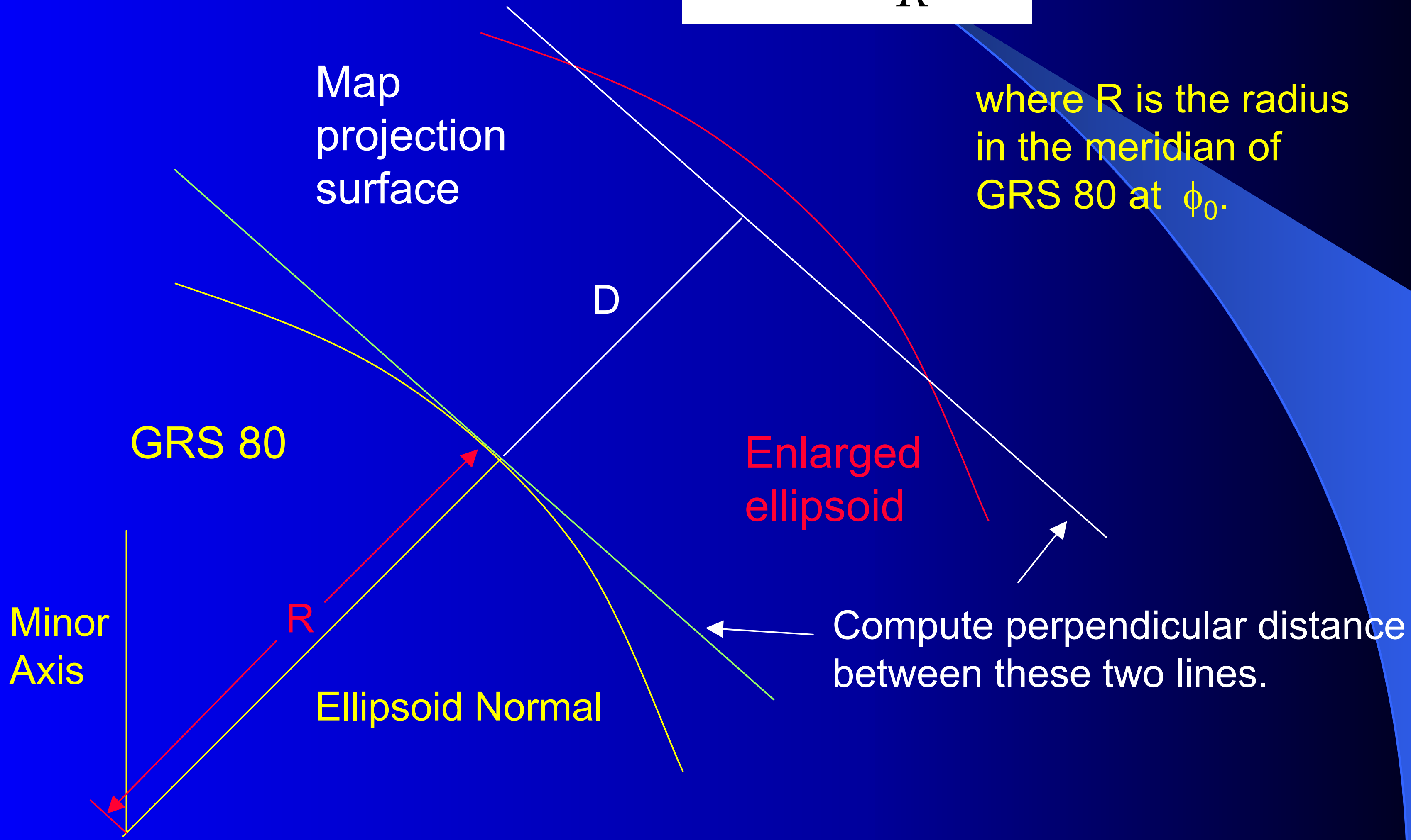
NOTE: Two sets of geodetic coordinates; one set of geocentric coordinates.

Approach to Strategy 1

To find k_0:

$$k_0 = \frac{R + D}{R}$$

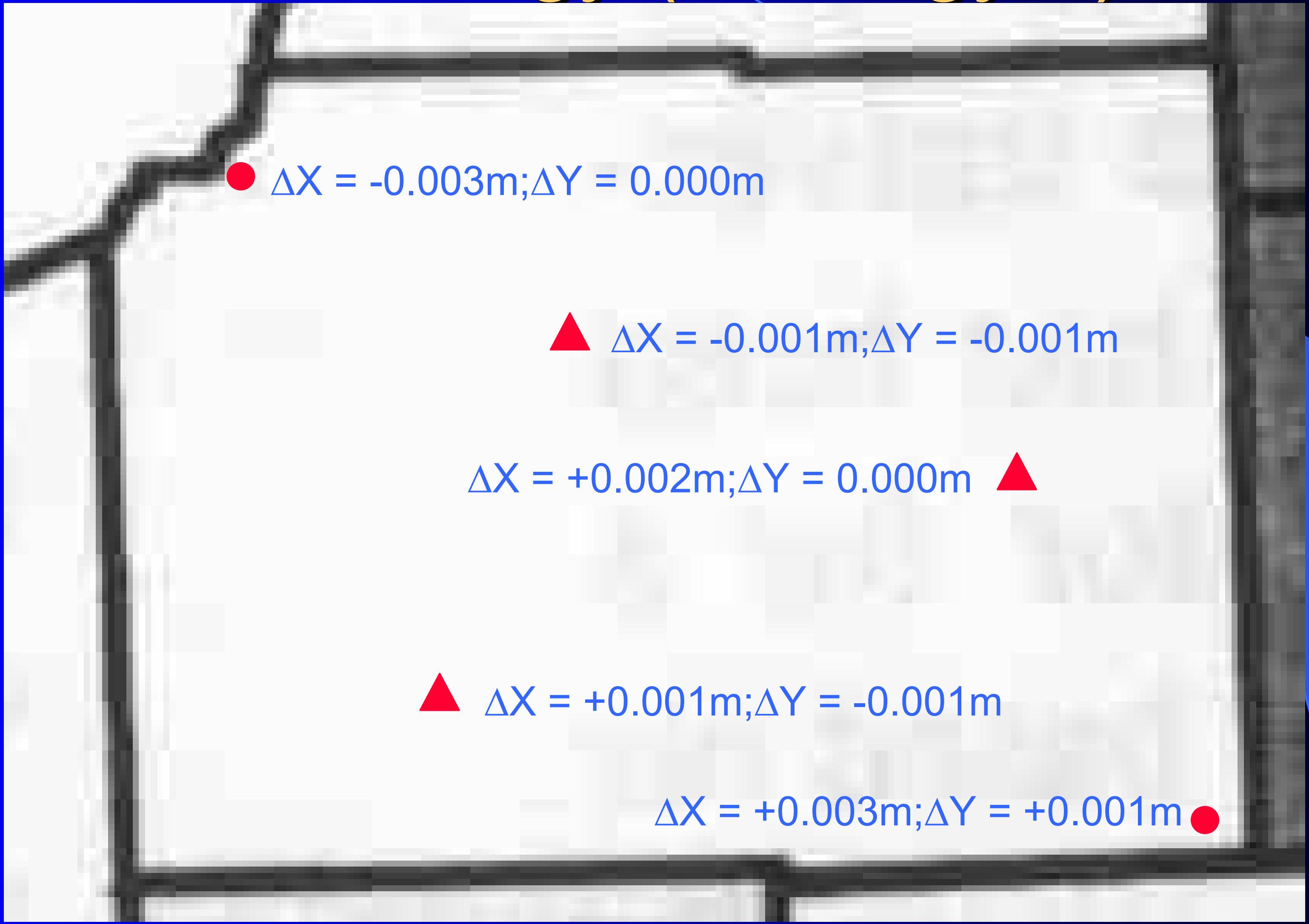
where R is the radius in the meridian of GRS 80 at ϕ_0.



Approach to Strategy 1

- There will be discrepancies because the two ellipsoids do not have the same shape.
- Compute best fit translation in Y (change in false northing) and scale from sets of coordinates of points in both the original and re-designed systems.
  - Points should be well-distributed across geographic extent.
- Apply these best fits to final re-designed parameters.

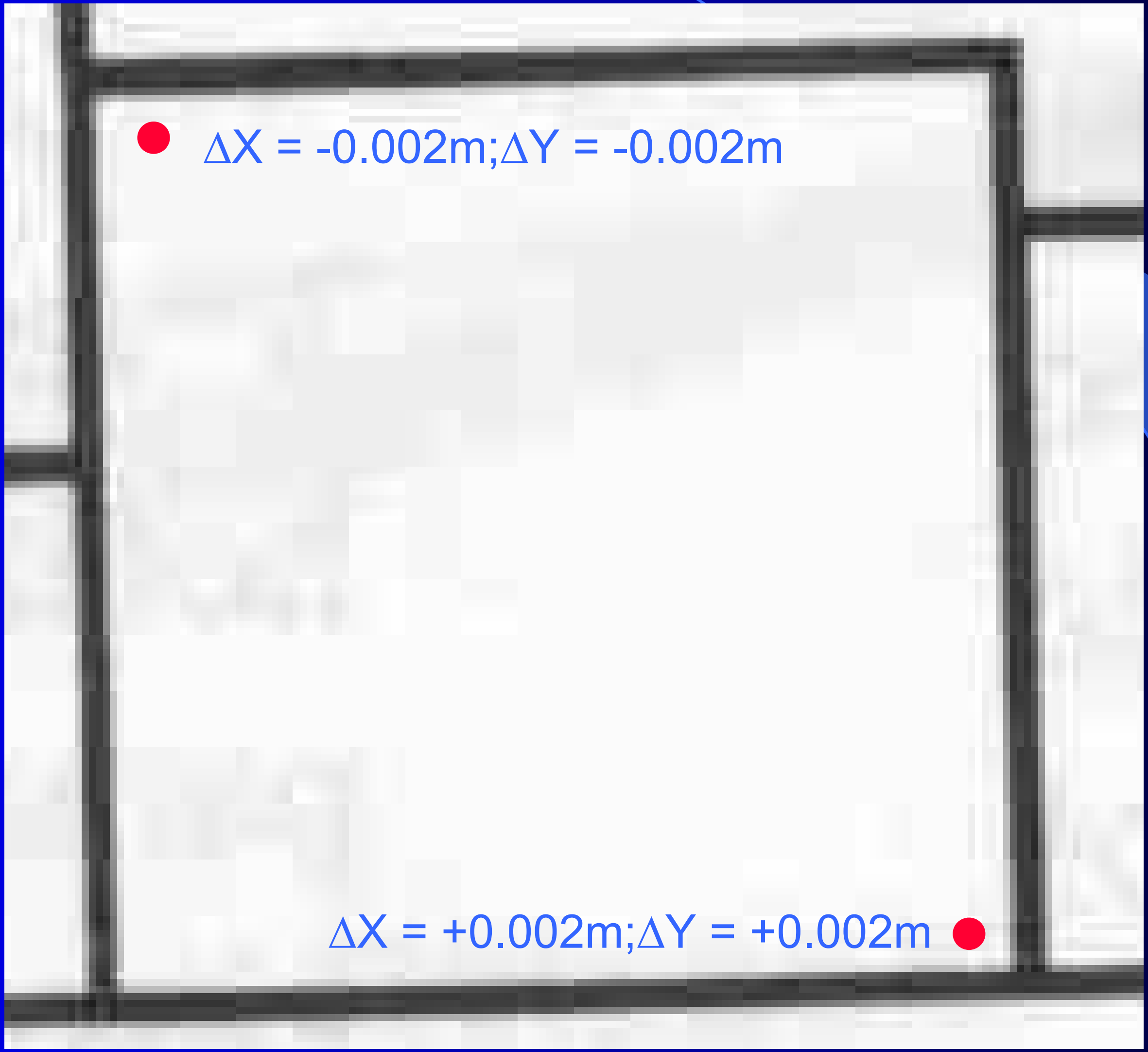
Dane County Test of Lambert Methodology (Strategy 1)



Approach to Transverse Mercator Re-Design

- Hold all parameters initially constant except k_0.
- Compute new k_0 in manner similar to that for Lambert re-design.
- Compute best fits for translation in Y (false northing) and scale.
- Apply best fits to final parameters.
- NOTE: Cannot hold map projection surface identical because the 2 cylinders have different shapes.

Lincoln County Test of Transverse Mercator Methodology



Conclusions

- Under the re-design, all WCCS would have a single, common datum based upon the GRS 80 ellipsoid.
- Initial tests indicate that WCCS can be re-designed to within 5mm or better.
- The WLIA Task Force has deemed 5mm to be a negligible difference.
- The WLIA Task Force is recommending re-design.

Summary

- Where are we headed?
  - Ted Koch

Summary

- **Where are we headed?**
  - WCCS redesign proposal approved by WLIA – October '04
  - WCCS redesign proposal approved by WLIB – November '04
  - WLIB approves $35 K for redesign costs
  - Contract for redesign through a single county using WLIB Strategic Initiative Grant

Summary

- **Where are we headed? (Continued)**
  - WCCS redesign completed by Sept. '05
  - WCCS redesign documentation completed by Dec. '05
  - During '05, TF will continue to address issues of registration, legislation and use
  - Prepare a TF final report
  - Continue to inform the community

Thank You

Questions???